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BASIC INFORMATION ON SAL (*SHOREA ROBUSTA*) FORESTS OF U.P. DEFICIENT IN NATURAL REGENERATION

By H. P. Bhatnagar

Forest Research Institute, Dehra Dun

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In the humid tropical region of the State of Uttar Pradesh, fringing the hills lies the main mass of the most valuable moist deciduous forests in which sal (*Shorea robusta*) is one of the important timber trees. The total forest area of U.P. is 39,873 square kilometres, of which the sal forests occupy an area about 7,090 square kilometres, and comprise the most valuable part of the forest domain.

Sal is roughly confined between 76° E longitude beyond Yamuna to 93° E in Darrang, and from 31° N latitude in Hoshiarpur to below 18° N in Bastar. In U.P. sal forests occur in a more or less continuous belt along the sub-Himalayan tract and the outer hills and plains, from Yamuna in the west to the Gandak river in the east. The normal altitudinal range in which sal occurs is between 152 to 915 metres, but in the outer Himalayas it sometimes ascends to about 1,220 metres or more and exceptionally to about 1,525 metres. In places especially in eastern U.P. the sal extends some distance into the plains. A very large portion of the natural distributional area of sal has been so radically altered by human occupation that in such areas it is no longer possible to determine the original limits of its distribution.

Climate

Sal occurs in an extensive region under an extreme range of climatic conditions. Some of the chief factors which characterise a climate are temperature and moisture. In relation to temperature the whole tract may be considered subtropical with a hot summer, a mild winter and rainy season. January is the coldest month when the minimum temperature goes down to between 5° C. and 7° C. The winter is characterised by rather warm days and cold nights with heavy dew which keeps

dripping till late in the day. At some of the high altitude habitats of sal there are occasional snowfalls. The maximum shade temperature is not much above 32° C. Mist and fog occur during nights and early mornings. Severe frost occurs in December, January and part of February specially in low-lying areas and in the western half of sal range. Sal seedlings are frost tender; it is almost impossible at places to establish sal seedlings in open situations. Light winter rains usually occur in December and January.

May and June are the hottest months. The maximum shade temperature generally reaches 35° to 41° C. During summer the air is often hazy with much dust and violent storms of short duration occasionally occur. Thunder storms accompanied by hail may also occur. "Loo" (hot westerly wind) blows strongly from April to June between 10 a.m. and 8 p.m. in the low-lying areas. In the nights in the submontane tracts "Dadu" (cold winds) blows which descends from the hills through the valleys from about 9 p.m. to 8 a.m.

The rainy season is marked by heavy rains and almost saturated atmosphere with very slight variation of temperature. The monsoon usually breaks about the middle of June and extends to the end of September, sometimes persisting well up to October. Except for a few winter showers from the retreating north-east monsoon current which usually falls towards the end of December or beginning of January, the rest of the year is practically dry. The outer hills catch the maximum amount of precipitation from the south-west monsoon. The heaviest fall usually occurs in July and August with an average of about 350 mm. or 380 mm. The average normal rainfall for the year varies between 890 mm. and 2,160 mm. The rainy season is generally followed by a short period of bright warm and damp weather which is generally close and oppressive.

Topography, Geology and Soil

Sal forests occur both in hilly country and on flat ground in the State of Uttar Pradesh. The northern part of the State, lying approximately between 77·5° and 81° E longitude and 29° and 31·3° N latitude, comprises of the Himalayan formation with the Siwaliks clinging to the southern region. The region forms the main watershed of the Ganga-Yamuna system of rivers, the former emerging on the plains at Hardwar and the latter further west near Dehra Dun. The rivers flow due south-east and then east through the alluvial plain. The configuration of the ground presents considerable variety. The Siwaliks are characterised by extremely rugged and broken ground with many steep and precipitous slopes, as also gentle and level slopes. As regards geology and soil, sal is found on a variety of geological formations and is capable of growing on various types of soil, provided the soil-water content is neither too low nor too high. The Siwaliks' topography belong to mountains but geologically to the plains. They are composed of the same material, hardly consolidated, that forms the deposits of the level plains of northern India. Broadly speaking three types of rock formations occur: (i) upper Siwalik conglomerate stage,

(ii) middle Siwalik and sand-rock stage and (iii) lower Siwalik (Nahan) sandstone stage. The underlying strata consist of beds of sandstone, gravel and conglomerate overlying hard rock which in places crops out on the surface. A very constant character of the conglomerate is the alternation of coarse and fine sand and of sandy loam and clay beds with it. The basis of sand-rock is a pure slightly ferruginous and sometimes felspathic sand with scarcely a particle of clay or with only an occasional pebble. Where pure limestone appears sal avoids that rock.

The soil presents endless variety from heavy clays to dry sand and boulder beds. In north and south Kheri forest divisions the underlying soil consists of alluvial formation of the Gangetic plains showing a succession of beds of sand and loam varying in depth according to the configuration of the ground. In the low alluvium the soil is very sandy and loamy sand, with Himalayan rocks embedded into the sand at a depth of 3 to 4·5 metres. In the high alluvium there are (i) a rich loamy sand with variable properties of clay, (ii) a moist sandy loam mixed with a fair proportion of decayed vegetable matter, (iii) a stiff sandy loam with a fair proportion of clay and a very slight admixture of humus and (iv) a micacious sand with a small proportion of clay or no clay at all, and markedly an absence of complete humus. Sal is never found in the sandy and shingly river-beds which are so common in the sub-Himalayan region.

Types of Sal Forests

In India Champion (1936) made the first attempt in classifying vegetation types. He considered the climate as nearly all potent factor determining the characteristics of a type. Floristic composition and soil factors were also considered to define seral and edaphic variants of a given climax (climatic) formation. He has given a workable classification of the sal forests of India. According to him the following types of sal forests occur in the State of Uttar Pradesh.

A. Dry Siwalik sal.—Rainfall rarely over 1,500 mm. and often under 1,250 mm. Minimum relative humidity for the year under 60 and for March under 45.

B. Moist sal.—Rainfall is between 1,375 and 1875 mm. Mean daily relative humidity of the year is between 60 and 70 and for March about 45–60. Champion has further subdivided both dry and moist sal forests as follows:

Dry type.—A_1 dry Siwalik sal,
A_2 dry Gangetic sal.

Moist sal.—B_1 moist western hill sal,
B_3 moist Gangetic high level alluvial sal,
B_4 moist Gangetic low level alluvial sal,
B_5 moist western low level clayey alluvial sal, and
B_6 West tarai sal.

Table I gives the area, typical locality of occurrence and status of natural regeneration of different types of sal forests of U.P.

TABLE I

Types of sal forests and some remarks

Type No.	Name of type	Area in U.P. in thousand hectares	Typical locality of occurrence	Natural regeneration
A_1	Dry Siwalik sal ..	98	Kalagarh, Dehra Dun, Lansdown, Ramnagar, Saharanpur forest divisions	Generally deficient. Very slow and difficult to come
A_2	Dry Gangetic sal ..	37	Ramnagar (Jaspur), Bahraich (Motipur), Dahulkhand (Saharanpur) forest divisions	Regeneration nil
B_1	Moist western hill (Siwalik) sal	156	Haldwani, Ramnagar, Kalagarh, Lansdown forest divisions	Adequate regeneration
B_3	Moist Gangetic high level alluvial sal	97	Dehra Dun North Kheri, Haldwani, Pilibhit, Ramnagar forest divisions	Regeneration fair to deficient. Slow in burnt grassy areas. Difficult to come
B_4	Moist Gangetic low level alluvial sal (App. sal chanders)	77	Pilibhit and South Kheri forest divisions	Regeneration usually fair (but annually frosted back)
B_5	Moist western low level clayey alluvial sal	20	Gorakhpur forest division	Regeneration fair to deficient (artificial)
B_6	West tarai sal ..	30	Nainital tarai	Regeneration deficient

QUALITY CLASS OF SAL TREES

Sal trees have been classified into different quality classes on the basis of differences in top height attained at a reference age. Qualities are distinguished into I, I/II, II, II/III, III, III/IV and IV. The fastest growth in unit time is shown by first quality trees and a proportionate decrease in growth is indicated by second, third and fourth qualities. Table II gives the height of the trees under different quality class (Griffith and Sant Ram, 1943).

TABLE II

Top height in metres of different quality trees of sal at 80 years of age

Quality	I	I/II	II	II/III	III	III/IV	IV
Height ..	Above 35	35-32	32-29	29-26	26-23	23-20	Below 20

NATURAL REGENERATION

The problem of natural regeneration is rather complicated in its varied aspects and whatever attempts have been made in the past do not seem to lead to definite conclusions. In Uttar Pradesh wherever available "advance growth" in woody seedlings or larger stages exists, it has been taken advantage of to successfully regenerate such areas by resorting to suitable subsidiary cultural operations. Large areas of sal forests, however, do not possess such "advance growth" and foresters are faced with the problem of obtaining regeneration *de novo* to replace the mature crop.

If we consider the regeneration and management techniques associated with different types of sal forests of Uttar Pradesh we find that the problem of natural regeneration is of importance only in A_1, A_2, B_3 and part of B_4 types of sal forests amounting to about 180,000 hectares. The progress of natural regeneration, mostly under selection or coppice with standard fellings, is considered adequate in parts of most of A_1, B_1 and part of B_4 types of sal forests, comprising about 285,200 hectares. B_5 type of sal forests comprising about 30,400 hectares is being well regenerated artificially. B_6 type of sal forests comprising about 4,000 hectares are not so important from the economic point of view though the regeneration here is deficient. Therefore, the foresters are confronted with the necessity of evolving a reasonably rapid regeneration technique to suit one-third and the most valuable third of the Uttar Pradesh sal forests. Basic information given further is limited only to areas in which the problem of natural regeneration of sal is more or less acute, *viz.*, A_1, A_2, B_3 and B_4 types of sal forests.

FLORISTIC COMPOSITION OF DIFFERENT TYPES

Dry Sal: A_1 Dry Siwalik Sal

Locality.—Soil is usually dry and this dryness may be due to topography leading to excessive run-off or the physical characteristic of the soil itself, rather than attributable to rainfall which is frequently quite high. The topography is broken, steep, stony and rugged with numerous knife-edged ridges where denudation is active. The altitudinal zonation of the type ranges from about 305 metres to 762 metres. Summer temperature reaches up to 38° C. Frost does not occur generally.

Annual rainfall ranges from 1,270–2,280 mm. The soil is generally porous, sandy, shallow and stony. Clay is also found intermixed. On the conglomerate the soil layer is shallow and mostly stony. The strata of the conglomerate and clay alternate in the Siwaliks and very often a shallow layer of clay covering conglomerate occurs.

The forest.—The forests are in sub-climax stage and exist as such under the influence of annual fires. The crop is unevenly aged with irregular canopy. Deciduous species are scattered about. Sal (*Shorea robusta*) trees generally occur in irregular mixture. The extent of these patches enlarges on deeper and moister soils, and they merge completely with deciduous forest on shallower drier soils. In general, the forests are of low quality varying from III to IV class.

The chief associates of *Shorea robusta* in the upper canopy are, *Anogeissus latifolia, Terminalia tomentosa*, and occasionally *Terminalia belerica, Adina cordifolia, Pinus roxburghii*, etc. The middle and the lower storey consist of *Ougeinia dalbergioides, Mallotus philippensis, Buchanania lanzan, Diospyros tomentosa, Semecarpus anacardium, Bauhinia recemosa*, other *Bauhinia* species, *Emblica officinalis, Acacia catechu, Zizyphus xylopyra, Nyctanthes arbortristis*. Bamboos occur sporadically on steep slopes. While most of the forest communities in these areas are composed of broad-leaved species, *Pinus roxburghii* occurs in some localities towards the rest of Siwaliks where there is substratum of conglomerate. Here it tends to form an upper storey with sal.

Grasses are light, consisting chiefly of *Heteropogon contortus, Chrysopogon montanus, Eulaliopsis binata, Bothriochloa intermedia* and occasionally *Desmostachya bipinnata*.

Undergrowth is scanty and is mainly of *Colebrookia oppositifolia, Clerodendrum infortunatum, Woodfordia fruticosa, Indigefera* species. The main climbers are *Vitis rependa, Milletia auriculata, Bauhinia vahlii* and occasionally *Ichnocarpus frutescens*.

Regeneration of sal (*Shorea robusta*) is very rare except in hollows and moist localities. Soil moisture is pronouncedly the limiting factor. On conglomerate formation where clay layers alternate with boulders, only a shallow layer of clay forms a substratum for tree growth. In such soils the undergrowth is predominantly grassy. With the loss of the clayey layer by erosion, sal tends to disappear as under such conditions the regeneration survives with difficulty. Due to frequent fires regeneration of principal species, except *Pinus roxburghii*, is very scarce. If these forests are protected from fire and grazing there are hopes for the spread of *Shorea robusta*.

A_2 Dry Gangetic Alluvial Sal

Locality.—Summer temperature rises up to 38° C. or seldom more. Rainfall ranges from 1,020–1,780 mm. Climatically this type is very much akin to moist high level sal, but may be differentiated

by greater exposure to hot winds and a higher summer temperature. Also the soil is much eroded.

The soil of the Jaspur forest consists of dry sandy to clayey alluvium. Fluctuations in water table take place at irregular intervals. The type occurs generally at the lower end of the rainfall range and the spring level is usually low.

The forest.—These forests seem to have emerged from moist sal, as a result of continued drought. Sal, being susceptible to arid conditions, has gradually died out making room for the preponderance of deciduous species. In this type, therefore, sal forms only a small percentage of the crop. This sal also is in a moribund condition; and the quality varies from III to IV. In moister patches it may attain II quality. Usually this forest is of an open nature with plentiful invasive grass.

In the moister places with more clayey soil the upper storey consists of *Shorea robusta* of II–III quality associated with *Terminalia tomentosa, Terminalia belerica, Lagerstroemia parviflora* and occasionally *Anogeissus latifolia.* The lower storey consists chiefly of *Mallotus philippensis, Miliusa velutina, Buchanania lanzan, Diospyros tomentosa, Piliostigma malabarica, Cassia fistula, Emblica officinalis* and *Ougeinia dalbergioides.*

Undergrowth is usually very light and consists mainly of *Clerodendrum infortunatum, Glycosmis pentaphylla, Murraya koenigii,* etc. Grasses are comparatively light and consist chiefly of *Imperata cylindrica, Erianthus ravennae* and *Saccharum spontaneum.* The main climbers are *Bauhinia vahlii, Vitis rependa, Pueraria tuberosa* and *Milletia auriculata.*

At places where the soil moisture is a limiting factor, retrogression is active and the upper storey consists of poor sal of III/IV–IV quality with such associates as *Terminalia tomentosa, Anogeissus latifolia,* etc. Lower storey consists chiefly of *Mallotus philippensis, Miliusa velutina, Aegle marmelos, Acacia catechu, Zizyphus xylopyra, Zizyphus jajuba, Dalbergia sissoo,* etc. Grasses are light and the chief species occurring are: *Imperata cylindrica, Erianthus munja,* etc. Undergrowth consists chiefly of *Adhatoda vasica, Vitex negundo, Clerodendrum infortunatum, Sida cordifolia, Moghania chapper,* etc. The main climbers are *Bauhinia vahlii, Milletia auriculata, Ichnocarpus frutescens* and *Pueraria tuberosa.* Occasionally *Dioscorea belophylla* is also met with.

Regeneration of sal is very scarce and seldom survives to reach the established stage. Only occasional seedlings attain established stage to maintain the status. Regeneration of sal is confined to open patches, *i.e.*, gaps in the upper storey with sparse middle storey trees (which suppress grass and weeds). Mortality amongst seedlings due to drought is fairly common. In frosty localities there is a complete absence of regeneration.

B_3 Moist Gangetic High Level Alluvial Sal

Locality.—The range in altitude varies from about 153 metres to over 610 metres. The temperature in the summer rises up to 41° C. or more and falls to about 2° C. in winter. Rainfall ranges from 1,020–1,780 mm., sometimes up to 2,530 mm., and occurs mostly during June to September. Occasional showers occur in winter months and heavy dew from November to March improves the moisture conditions. Hot dry winds during summer are quite characteristic. Frost damage is limited and is mostly determined by local topography. Generally, frost is common where cold air flows from the hills and where the main rivers debouch on the plains as in South Kheri and Pilibhit divisions, on the Sharda river and also in valleys where circulation of air is hindered.

Throughout the B_3 type of forests only alluvial soils are found which vary considerably in maturity and in depth and the amount of gravels and boulders, underlying the top soil. Deep soils, however, are common, although subjected to erosion. Only old soils carry this type of forest.

The forest.—The best quality of sal occurs in B_3 type. The forests are typically even-aged in groups and large proportion of the older stands are deficient in regeneration. Sal constitutes up to 90% of the crop. The distribution in even-aged groups is due particularly to past treatment combined with rigid protection. The younger age class of sal is deficient.

The quality of sal generally varies from first to third but the average quality is second. At places where the soil is rich sandy loam, sal is of good quality (I to II/III) and well stocked. But where the soil deteriorates and becomes very sandy and drier, the sal is of poor quality. In well-stocked sal forests the upper canopy consists, apart from sal, of *Terminalia tomentosa* (from 5–15%; it increases near grassy blanks and depressions), *Syzygium cumini* (fairly common in moist places), *Terminalia belerica*, *Adina cordifolia*, *Lagerstroemia parviflora*. The under storey consists chiefly of *Mallotus philippensis* which forms almost impenetrable thickets. Other species are, *Kydia calycina*, *Stereospermum suaveolens*, *Lannea grandis*, *Garuga pinnata*, *Holarrhena antidysenterica*, *Semecarpus anacardium*, *Piliostigma malabaricum*, *Miliusa velutina*, *Putranjiva roxburghii*, *Cassia fistula*, *Grewia* spp., *Bauhinia racemosa*, *Diospyros tomentosa*, *Schleichera eleosa*, *Casearia tomentosa*, *Ehretia laevis*, etc.

The undergrowth consists chiefly of *Clerodendrum infortunatum*, *Murraya koenigii*, *Pogostemon plactranthoides*, *Moghania chapper*, *Moghania macrophylla*, *Helicteres isora*, *Colebrookia oppositifolia*, *Ardisia humilis*, *Indigofera pulchella*, *Malva sylvestris*, *Sida humilis*, *Euphorbia* sp., *Adiantum* sp. Common climbers are *Tiliacora recemosa* (which is specially very abundant in North Kheri forest division where its trailing stems cover almost the whole of the surface and there it is found climbing on almost all trees up to great heights), *Milletia auriculata*

(quite abundant), *Butea parviflora, Acacia pinnata, Smilax prolifera, Dioscorea belophalla, Ichnocarpus frutescens, Vitis repanda* and occasionally *Tinospora cordifolia.* Chief grasses are *Themeda arundinacea, Sclerostachya fusca, Imperata cylindrica, Narenga porphyrocoma.* Any opening in the canopy is marked by stronger development of the grasses, especially *Erianthus munja.* Where the canopy is fairly diffuse grasses are quite inconspicuous. *Loranthus longiflorus* is quite abundant on sal trees.

Regeneration of sal is fairly common and is found mostly in whippy stage. Woody advanced growth and small subpressed poles are found in abundance in certain parts as in Dehra Dun. Usually the established saplings are sparse in this type. In moist localities where high quality sal is found, regeneration even in the recruitment stage is wanting. Good seed years are frequent but the seedlings die back year after year till a thick carroty root stock is formed and a strong woody shoot is sent up. Rigid fire protection is perhaps partly responsible for the deficient regeneration as it has favoured evergreen weeds like *Mallotus philippensis, Tiliacora recemosa* and *Milletia auriculata* which have developed into dense masses and hinder the development of sal seedlings.

Termite mounds are very common in this type and indicate well-drained soils.

B_4 Moist Gangetic Low Level Alluvial Sal and Sal Chanders

Locality.—The climate of this type is almost identical with that of B_3 type of sal (*Shorea robusta*) forests but frost here is most prevalent specially in sal chanders. Summer temperature rises up to 38° C. or more. Rainfall is between 1,020 and 1,780 mm. The soil is usually loamy clay, impervious and badly drained, and of limited depth. The subsoil is typically dry and sandy. In the sal chanders, the soil and especially subsoil are again typically sandy although clayey patches also occur. Drought mortality may be very serious, resulting in wholesale death of sal. The soil shows alternation of beds of sand and loam. Their thickness, however, depends on configuration. Water table fluctuates between 3 and 9 metres. Extensive swamps often adjoin the forests.

The forest.—These forests are supposed to represent a subclimax stage. Undoubtedly in some places the forest is the normal climax, which is stable under the prevailing ecological conditions of soil, drainage and subsoil water-supply. The quality of these forests is inferior than that in B_3 type. It is generally III, grading to II/III in a few places. The crop is generally understocked. Sal is by far the most dominant species in the upper storey and forms about 70–90% of the crop. Density is fair, being 0·5 or more. Upper storey consists of *Terminalia tomentosa, Lagerstroemia parviflora, Terminalia belerica, Adina cordifolia, Albizzia lebbak,* etc. The lower storey consists chiefly of *Mallotus philippensis, Stereospermum suaveolens, Kydia calycina, Lannea grandis, Holarrhena antidysenterica, Bridelia retusa, Milusa*

velutina, *Syzygium cumini*, *Cassia fistula*, *Semecarpus anacardium*, *Emblica officinalis*, *Butea monosperma*, *Diospyros tomentosa*, *Casaeria tomentosa*, *Garuga pinnata* and *Bauhinia* sp. The shrub layer and ground floor vegetation consists of *Clerodendrum infortunatum*, *Pogostemon plectranthoides*, *Miliusa velutina*, *Helicteres isora*, *Murraya koenigii*, *Moghania chapper*, *Sida humilis*, *Malva sylvestris*, etc. Climbers too are plentiful and consist of species like *Butea parviflora*, *Milletia auriculata*, *Bauhinia vahlii*, *Pueraria tuberosa*, *Tiliacora recemosa*, etc. ; practically all the species are also met with in sal chanders. The grasses are tall and dominant in the open and the main species are *Themeda arundinacea*, *Saccharum spontaneum*, *Erianthus munja*, *Eulaliopsis binata*. In sal chanders *Themeda arundinacea* is sometimes so tall and dense that the chanders are almost impenetrable. At some places the grasses are shorter and include a fair proportion of *Eulaliopsis binata*. Sal regeneration is present but is not profuse. The younger age classes are deficient. Very often *Milletia auriculata*, *Tiliacora recemosa* with *Mallotus philippensis* form impenetrable thickets inhibiting natural regeneration of sal.

Sal chanders have plenty of whippy regeneration, and stunted coppice growth of sal is mixed with tall coarse grasses. In winter the sal shoots are killed by frost but the root stock survives and sends up shoots every year, which are again killed back in winter by frost and in summer by intense grass fires.

Termite mounds are plentiful. Termites are also found on the bark of almost all trees.

Table III gives a summarized statement on the basic information on the regeneration status, phytosociological studies and on soil of the different forest areas described on previous pages. This is based on the studies conducted by the author on "Ecologico-physiological studies on sal (*Shorea robusta*) forests of Uttar Pradesh".

Plant Communities

Floristic composition of some representative samples of A_1, A_2, B_3 and B_4 types of sal forests has been worked out to differentiate the constituent plant communities and their successional trends. In all, seven plant communities were recognised, they are, *Sal-Anogeissus Colebrookia*, *Sal-Terminalia-Glycosmis*, *Sal-Ougeinia-Carissa-Sida*, *Sal-Terminalia-Moghania*, *Sal-Lagerstroemia-Pogostemon*, *Sal-Syzygium-Randia-Ageratum* and *Sal-Ougeinia-Colebrookia* communities. Successional relationship among different communities indicate that in the dry sal type *Sal-Anogeissus-Colebrookia* and *Sal-Ougeinia-Carissa-Sida* communities are lower stages which tend to progress towards *Sal-Terminalia-Glycosmis* community under improved biotic conditions. Similarly in the moist sal types *Sal-Ougeinia-Colebrookia* community tends towards *Sal-Terminalia-Moghania* community. *Sal-Terminalia-Moghania* and *Sal-Lagerstroemia-Pogostemon* communities are more or less stable aggregations under normal conditions but occur in different climatic and forest zones and in respect of stability and maturity they

occupy a corresponding position. *Sal-Terminalia-Moghania* community tends to change into *Sal-Syzygium-Randia-Ageratum* community under damper conditions and may thus be a post-climax stage occurring specially in favourable situations.

Phytosociological studies have indicated that *Shorea robusta* is the dominant species of all these communities with high frequency and density and sociability. Other tree species, which are characteristic of a particular community, attain high dominance and sociability only in the community which they serve to characterize. *Mallotus philippensis* in the lower storey is the most dominant species in all the communities. *Clerodendrum infortunatum* is also found to occur with high dominance and sociability in the communities of moist sal type. The characteristic species of herbs and shrubs-stratum occur in greater dominance and sociability only in the corresponding communities.

Succession Status of Dry and Moist Types of Sal Forests

Succession studies in the dry and moist sal types indicate that there is evidence of both main lines of successional changes, namely progression and retrogression. The dry sal types (A_1 and A_2) ultimately degrade into a grassy savannah of dry type passing through the mixed miscellaneous stages containing species like *Diospyros tomentosa*, *Anogeissus latifolia*, *Holarrhena antidysenterica*, *Aegle marmelos*, etc. The primary succession in the dry type starts from grassland association with species like *Saccharum spontaneum*, *Erianthus munja*, etc., to *Acacia-Dalbergia* which leads to mixed miscellaneous stage containing *Holoptelea integrifolia*, *Salmalia malabaricum*, etc. This may retrograde to deciduous forests or to mixed forests with sal and finally to a dry savannah.

In the moist sal types the primary succession starts from grasses and leads to mixed forests of sal with *Terminalia tomentosa*, *Syzygium cumini* and others after passing through mixed miscellaneous seral stages with *Acacia catechu*, *Dalbergia sissoo* and later on *Holoptelea integrifolia*, *Adina cordifolia*, *Albizzia procera*, etc. The moist sal may degrade to dry sal type than to mixed miscellaneous forest and ultimately to dry savannah. In localities with high water table and under moister conditions, the retrogression may proceed towards savannah with tall grasses, through moist miscellaneous forest containing pockets of grassland. The tall grass savannah may be more or less stabilized as a sort of post-climax association.

Indicator Value of Species for Sal Natural Regeneration

The kinds of communal relationships among plants are manifold, but not all have phytosociological value. Therefore, to find out the relation of different species with regard to sal regeneration, *i.e.*, the indicator value of plant studies were conducted in different forest types of U.P. with regard to indicator value of different species, it can be said that usually the species occurring in the shrubs and herbs strata are

TABLE

Basic information on regeneration status, phytosociology

No.	Locality	Community and forest type (Champion)	Quality	Soil
	1	2	3	4
	Good regeneration			
1	Saurata 7 N. Kheri	*Sal-Terminalia-Moghania* (B_3)	I	Clay loam
2	Mailani 43 S. Kheri	do. (B_4)	II	Sandy loam
3	Asarori 10 Dehra Dun	*Sal-Syzygium-Randia-Ageratum* (B_5)	III	do.
4	Bhandarpani 1 Ramnagar	*Sal-Terminalia-Glycosmis* (A_1)	III	do.
5	West Lahra 7 Gorakhpur	*Sal-Terminalia-Moghania* (B_3)	III	Sandy clay loam
6	Samanthapla 2 Haldwani	*Sal-Lagerstroemia-Pogostemon* (B_3)	II	Sandy loam
7	Motipur 34 Bahraich	*Sal-Terminalia-Moghania* (A_2)	IV	Sandy clay loam
	Poor regeneration			
8	Sainkot 3 Dehra Dun	*Sal-Ougeinia-Colebrookia* (B_3)	IV	Sandy loam
9	Bhadraula 4 N. Kheri	*Sal-Terminalia-Moghania* (B_3)	II	Clay loam
10	Jaspur 43 Ramnagar	*Sal-Anogeissus-Colebrookia* (A_2)	III	Sandy loam
11	Bharibaisi 2 Gorakhpur	*Sal-Terminalia-Moghania* (B_3)	III	do.
12	Mailani 28 S. Kheri	*Sal-Lagerstroemia-Pogostemon* (B_4)	III	do.
13	Lakmanmandi 4 Haldwani	do. (B_3)	I	do.
14	Motipur 69 Bahraich	*Sal-Terminalia-Glycosmis* (A_2)	IV	do.

Columns 6–11. Numerals relate to the community, numerals in italics relate to the
,, 6–10. Localities from where soil was collected but regeneration counts not done of sampling carried out elsewhere. The general status of the regenera-
Column 10. % frequency is the % of quadrats stocked with seedlings.
,, 11. % composition is the number of sal seedlings expressed as a % of the
,, 12. Dominance: * Indicates a small number of individuals; area covered
1 Indicates a large number of individuals; area covered
2 Indicates numerous individuals occupying at least
,, 13. Sociability: 1 Indicates seedlings occurring individually.
2 Indicates seedlings occurring in small groups.
,, 1. Numerals after the locality indicate the compartment number.

III

and soil of sal forests of Uttar Pradesh

Regeneration status of community	No. of quadrats studied	No. of quadrats stocked	Av. No. of seedlings per stock quadrat	Av. No. of seedlings per quadrat	% Frequency	% Composition	Dominance	Sociability
5	6	7	8	9	10	11	12	13
Good	(60)	(50)	(1·24)	(1·03)	(83·3)	..	2	2
	(20)	*(12)*	..	..	*(60)*	*6·0*	..	..
do.	(60)	(50)	(1·24)	(1·03)	(83·3)	..	2	2
	(20)	*(18)*	..	..	*(90)*	*10·1*	..	..
do.	(60)	(42)	(1·24)	(0·87)	(70·0)	..	2	2
	(20)	*(18)*	..	..	*(90)*	*17·1*	..	..
Fair	(60)	(36)	(1·28)	(0·77)	(60·0)	..	2	1
	(20)	*(14)*	..	..	*(70)*	*8·0*	..	..
Good	(60)	(50)	(1·24)	(1·30)	(83·3)	..	..	..
Fair	(60)	(40)	(1·30)	(0·87)	(66·6)	..	2	2
	(20)	*(16)*	..	..	*(80)*	*15·0*	..	..
Good	(60)	(50)	(1·24)	(1·03)	(83·3)	..	..	..
Fair	(40)	(26)	(1·39)	(0·90)	(65·0)	..	2	1
	(20)	*(8)*	..	..	*(40)*	*7·0*	..	..
Good	(60)	(50)	(1·24)	(1·03)	(83·3)	..	..	..
Poor	(60)	(18)	(1·22)	(0·36)	(30·0)	..	*	1
	(20)	*(6)*	..	..	*(30)*	*3·4*	..	..
Good	(60)	(50)	(1·24)	(1·03)	(83·3)	..	..	..
Fair	(60)	(40)	(1·30)	(0·87)	(66·6)	..	2	2
	(20)	*(6)*	..	..	*(30)*	*2·6*	..	..
do.	(60)	(40)	(1·30)	(0·87)	(66·6)	..	..	..
do.	(60)	(36)	(1·28)	(0·77)	(60·0)	..	..	..

locality mentioned in column 2.
in transects are bracketed; the regeneration data relate to the community on the basis tion was noted ocularly.

total number of plants in the 1 metre square quadrat.
being small.
being small.
1/20th area.

better indicators than the tree species. No species of the upper storey is definitely indicative of poor sal regeneration. In most of the cases tree species of the upper storey do not show any correlation with sal regeneration except *Terminalia tomentosa* and *Lagerstroemia parviflora* which are rather associated with better sal regeneration, but only in *Sal-Terminalia-Moghania* and *Sal-Syzygium-Randia-Ageratum* communities. In case of lower storey tree species only very few are closely associated with sal regeneration. *Mallotus philippensis* in the lower storey is generally found to occur in dense crowded masses in places where sal regeneration is poor. Usually its occurrence is linked with poor or comparatively poor sal regeneration. Its inhibiting influence is felt the most when it abounds and perpetuates either in seedling state or shrubby condition.

Grasses generally are indicators of poor sal regeneration except for species like *Imperata cylindrica* and *Erianthus munja* which may be associated with good or bad regeneration conditions depending upon the successional stage of the lower strata. A species may be on its way into the floristic complex at one stage and on its way out at another and for a correct understanding of the roles played by these species it is necessary to have an equally thorough understanding of the dynamics of succession in the community concerned. Speices of grasses like *Erianthus munja*, *Eulaliopsis binata*, *Imperata cylindrica*, *Themeda arundinacea*, *Saccharum spontaneum*, *Narenga porphyrocoma*, *Chrysopogon montanus*, etc., are peculiarly prone to play such double roles due to their greater association with the local and microhabitat conditions and the changing pattern of ground cover associations. Nevertheless some of these have a greater indicator value than others for example *Narenga porphyrocoma* which is common in grassy areas in moist sal forests usually acts as a good nurse to sal and it is usually found on soils suitable for sal regeneration; contrary to this *Saccharum spontaneum* occurring in dry or marshy localities indicates conditions inimical to sal regeneration.

The species which are most consistently associated with sal regeneration in the various communities are comparatively few in number, the most important of them are *Lagerstroemia parviflora*, *Syzygium cumini*, *Litsaea chinensis*, *Miliusa velutina*, *Clerodendrum infortunatum*, *Pogostemon plectranthoides*, *Moghania chapper*, *Adiantum* sp., *Ophioglossum* sp. and *Oplismenus compositus*.

There are also certain species which in general indicate conditions unfavourable for the growth of sal. The chief among these are *Diospyros tomentosa*, *Schleichera oleosa*, *Careya arborea*, *Holarrhena antidysenterica*, *Aegle marmelos*, *Mitragyna parvifolia*, *Mallotus philippensis*, *Saccharum spontaneum*, *Heteropogon contortus*, *Zizyphus* spp. Most of these species occur in dry habitats as constituents of the adjacent dry deciduous forests which are too dry, frequently burnt and excessively grazed to support sal. These species are more xerophytic than sal and are characterized by drought-hardiness, fire resistance and

with the ability to subsist on bouldry and excessively drained or too clayey and stiff soils which are in general unsuitable for sal regeneration.

From these indicator species representing conditions suitable of unfavourable for the regeneration of sal, it may well be deduced that certain species do not seriously compete with sal for moisture and nutrients while others do so to a severe degree. The competition so set in makes all the difference. This contention is also supported by the results of an investigation on the water requirements of sal and other species in seedling stage (Bhatnagar, 1958).

Biotic Factors

The important biotic factors operative in the sal forests of U.P. are as follows: Fire is the most important factor caused by human agency. Adverse effects of fires are many, usually the burnt-over areas abound in grass and very often a secondary retrogression is set in, which causes abundance of grasses like *Erianthus munja*, *Imperata cylindrica* and shrubs like *Clerodendron infortunatum*, *Mallotus philippensis* and *Milletia auriculata* to the detriment and inhibition of sal regeneration. Uncontrolled or excessive grazing has very serious adverse effects on the regeneration of sal and other forest tree species. Trampling and browsing of regeneration is common and the soil is hardened to the detriment of germination of seeds. Erosion is accentuated and thorny unpalatable shrubs like *Carissa opaca* increase proportionately. Excessive grazing also arrest seral development of vegetation and sometimes leads to retrogression. Browsing and nibbling animals do great damage to forest saplings. Excessive damage to sal is done by animals like Sambhars, chital, kakar, nilgai, gond and other browsing animals. Insects are also responsible for great damage often on an extensive scale. By far the more seriously damaging insect in sal forests is the sal longicorn borer (*Hoplocerambyx spinicornis*), defoliating insect like *Ascotis selenaria* are quite common. Rot in mature and over-mature sal trees are very common due to fungus growth. Most important fungi are root and collar rot of sal caused by *Polyporus shorea*. Climbers also sometimes do considerable damage to sal saplings and poles. The most common climbers are *Milletia auriculata*, *Bauhinia vahlii* and *Tiliacora recemosa*. In North Kheri forest division *Milletia auriculata* and *Tiliacora recemosa* together with *Mallotus philippensis* form dense impenetrable thickets which restrict the natural regeneration of sal.

Summary

The problem of natural regeneration of sal (*Shorea robusta*) in many forests of Uttar Pradesh is rather complicated in its varied aspects. Sal is known to die back or persist in a stagnating condition for periods up to 30–40 years so that the reproduction of this species cannot be secured at will. Basic information with regard to distribution, topography, geology and soil is described in general for different types of sal forests occurring in the State of Uttar Pradesh. Some account

of regeneration status, phytosociology, soil, succession and indicator value of species is described in particular for those sal forest types in which the problem of sal natural regeneration is acute, *viz.*, A_1, A_2, B_3 and B_4 types.

Acknowledgements

I am grateful to Sri. S. K. Seth and Sri. M. A. Waheed Khan for guidance, to Dr. G. S. Puri for suggesting me this problem and to Dr. R. Misra for suggestions. My thanks are due to Sri. Harbans Lal and various forest officers of the U.P. Forest Department for help and other facilities during tours.

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MORPHOLOGY OF *HIBISCUS CANNABINUS* L. × *HIBISCUS RADIATUS* CAV. HYBRIDS

By S. C. Rakshit, P. Sanyal* and B. C. Kundu

Jute Agricultural Research Institute, Barrackpur, West Bengal

(Received for publication on April 2, 1960)

In order to incorporate disease resistance character to *Hibiscus cannabinus* L., an important substitute for jute but which is highly susceptible to various diseases, attempts were made to hybridize *H. cannabinus* ($2n = 36$) with five other disease resistant species of *Hibiscus*, *viz.*, *H. sabdariffa* ($2n = 72$), *H. radiatus* ($2n = 72$), *H. panduraeformis* ($2n = 24$), *H. lunariifolius* ($2n = 40$) and *H. vitifolius* ($2n = 34 \pm 1B$). Successful hybrids were obtained only from crosses between *H. cannabinus* and *H. radiatus* in both directions, but the percentage of pod setting was more (75·33%) when *H. radiatus* was used as the female parent. The study on pollen fertility and seed formation of the parents and F_1 hybrids in this cross indicated that in general the production of full seeds in the F_1 as compared to parents was extremely poor, the percentages were 87·14, 90·21 and 0·45 in *H. cannabinus*, *H. radiatus* and F_1 hybrid respectively. The pollen fertility similarly in the F_1 hybrids was also very low (22·09) as compared to *H. cannabinus* (96·58%) and *H. radiatus* (96·24%). As a result of such high percentage of sterility in the F_1s only few plants could be obtained in F_2 for morphological studies. The present paper deals with the phenotypic characters of the parents and the F_1 and F_2 hybrids.

Material and Methods

Morphological characters of both the parents *H.* (*radiatus*, *H. cannabinus*) and F_1 hybrid were recorded during 1954 and 1955.

For the study of F_2 plants, only full and partially full seeds were sown during two years (1955 and 1956) but the germination in F_2 families in both the years was extremely poor. During these two years only 21 and 20 plants were obtained at maturity. Hence phenotypic classification of F_2 population and their statistical analysis could not be done. Morphological records of all the F_2 plants on the basis of the inheritance of parental and other new characters were recorded in both the years and have been summarised in the present investigation.

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* Present address: Agricultural Research Institute, Sabour, Bihar.

Observations

Parents and F_1 hybrids.—The morphological characters of *H. cannabinus*, *H. radiatus* and the F_1 hybrid are given in Table I.

From Table I it can be seen that many of the characters of the F_1 hybrid were intermediate; a few like stipule length, unjointed peduncles, non-bifurcated epicalyx, ovoid capsule, blackish-grey seeds were that of *H. cannabinus* and the serration of lamina margins, spathulate tip of segments of epicalyx, absence of prominent gland on the midrib of calyx, etc., were like *H. radiatus*. The intermediate condition of branching habit, presence of a few prickles on the stem, corolla colour, size of calyx lobes, colour and size of staminal column, shape of ovary and capsule, etc., need special mention. Plate XIV shows some of the intermediate conditions of F_1 hybrids. It was also noticed that the characters in F_1 hybrids were the same when either *H. radiatus* or *H. cannabinus* was used as the male or female parent.

F_2 population.—Of the total of 41 F_2 plants studied during two years (1955 and 1956), 17 plants were like *H. cannabinus* and 3 like the F_1s. No plant with completely *H. radiatus*-like characters could be obtained in any of these years. The remaining 21 plants besides some of the parental and F_1 characters also showed some abnormal and new morphological characters. These new characters in F_2 population were mostly associated with the peculiarities in the vegetative as well as in the floral parts. The occurrence of hexamerous flowers (Text-Fig. 1 *a*), unequal and crumpled petals (Text-Fig. 1 *b*), closed flowers (Text-Fig. 1 *c* and *d*), presence of staminode, irregular development of staminal column and their union with petals all through, poorly developed cap-like anthers, bifurcation of filaments and presence of one anther on each portion, dome-shaped ovary, irregular development of 6–8 chambered ovary, palmately 3-lobed leaves, stunted growth of the stem, plants without any flower, etc., were amongst such peculiarities.

The percentage of seed setting and pollen fertility in F_2 plants varied between 0 and 33·87 and 0 and 88·52 respectively, indicating thereby the wide variation.

Discussion

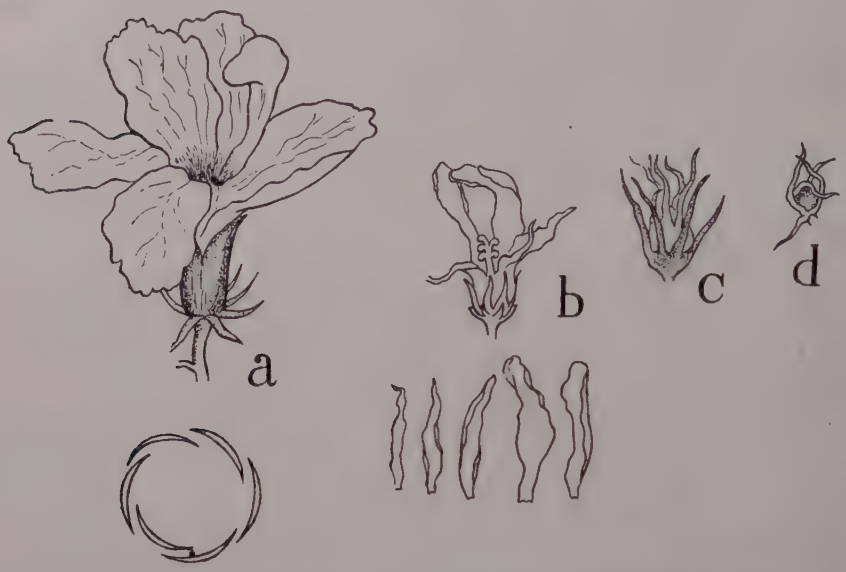
So far only Toxopeus (1948) made preliminary attempts in crossing eight different species of *Hibiscus* and reported the successful hybridization of *H. cannabinus* with *H. radiatus* and obtained viable seeds when only *H. radiatus* was used as the female parent. But no phenotypical characters of the hybrids were described either in F_1 or F_2 generations. Only it was mentioned that in the F_3 generation of this cross, many parental characters appear to be linked. Pollen fertility and normal seed formation were higher in those plants where the parental characters stick together. In the case of recombination of characters, however, the pollen fertility and seed formation were very low ranging from 0 to 50%.

TABLE I

Showing morphological difference of the parents and F_1 hybrid

Characters	*H. radiatus*	*H. cannabinus*	F_1 hybrid
Plant height	0·9–1·8 m.	2·4–3·6 m.	1·2–2·4 m.
Base diameter	1·0–1·5 cm.	1·5–2·5 cm.	1·0–2·0 cm.
Stem	Bushy, branching, prickles a few or 0.	Less branched, with prickles.	Branching intermediate, prickles a few or 0.
Stipule	Linear, 2–2·3 cm. long.	Linear 0·8–1·0 cm. long.	Linear 0·5–0·8 cm. long.
Petiole	2–8 cm. long, prickles a few or 0.	4–18 cm. long, with prickles.	4–6 cm. long, prickles a few.
Lamina	3–5 deeply palmately lobed, smooth, margin deeply serrated.	5–7 deeply palmately lobed, rough, margins serrated.	3–5 deeply palmately lobed, smooth, margins deeply serrated (more like *H. radiatus*).
Flower	Stalk jointed, flower large showy, deep crimson-red.	Stalk unjointed, flowers large showy, yellow with crimson red centre.	Stalk unjointed, flowers large showy, light violet with deep red centre.
Epicalyx	Segments usually 9, linear, tip spathulate with a linear small appendage.	Segments usually 8, linear, acute.	Segments usually 8–10, linear, tip spathulate without any appendage.

Calyx	5–lobed; lobes 4 times the length of the cup, gland on the midrib not prominent.	5–lobed; lobes 2–2·5 times the length of cup, one big green gland on each midrib, tomentose.	5-lobed; lobes 3 times the length of cup, gland on the midrib not prominent, tomentose.
Corolla	Petals 5, deep crimson-red.	Petals 5, yellow with deep crimson red in lower inner portion.	Petals 5, light violet with deep red in lower inner portion.
Staminal column	Usually 3·0 cm. deep crimson red.	Usually 1·5 cm. light red.	Usually 1·5–2·0 cm. red.
Ovary	Broadly ovoid, usually 0·6 cm. long.	Ovoid, usually 0·7–0·8 cm. long.	Globose-oviod, usually 0·4–0·5 cm. long.
Fruit	Capsule broadly ovoid, easily dehiscent.	Capsule ovoid, longer than *H. radiatus*, easily dehiscent.	Capsule ovoid like *H. radiatus* but smaller in size, not easily dehiscent, locules in most cases empty.
Seed	Reniform, brownish.	Reniform, greyish-black, almost double than *H. radiatus*.	Reniform, slightly greyish-black, intermediate in size.



TEXT-FIG. 1. Drawing of some floral peculiarities in the F_2 population. (*a*) showing hexamerous flower, (*b*) showing unequal and crumpled petals, (*c* and *d*) showing closed flowers.

It is observed in the present investigation that many of the characters in F_1s are incompletely dominant, few like *H. cannabinus* and the rest like *H. radiatus*. Similar behaviour of characters in the F_1s was also noticed in the reciprocal crossings, thus showing no evidence of cytoplasmic influence.

A comparative morphological study of the F_1 and F_2 hybrid progenies indicate that while the characters in F_1s are uniform with respect to certain parental and other intermediate characters, in the F_2s it is highly variable. The F_2 generation is represented by the different recombinations of morphological characters from the parents to some completely new recombination types which differ from the parental species. Many of these recombination types are quite pronounced in their vegetative as well as their floral characters as mentioned earlier. Polyphylly (increase in the number of petals, bifurcation of filaments with anther in each portion, 6–8 locular ovary, etc.) and the union of stamens with petals all through (petaloidy of stamens) indicate the repetition of primitive nature in some F_2 population.

The occurrence of new recombination types in F_2 generation usually depends on the genetic difference between the parental species in any cross. In the present cross of *H. radiatus* × *H. cannabinus*, many new recombination types appear in F_2 generation with different grades of fertility. The variation of fertility in the recombination types was, however, recorded in F_2 whereas Toxopeus (1948) reported such variation only in the F_3 generation. The new recombination types in F_2

do not breed true, hence there is no evidence of non-homologous translocation or segmental interchange between the two species. A number of examples of such aberrant types have been cited in the crosses of the genus *Antirrhinum*, *Argemone*, *Viola*, etc., by Stebbins (1951). Griggs (1937) has emphasised the significance of such types in the origin of cultivated plants. The possibility, therefore, exists that some such new types may become established after some generations which may also contribute to evolutionary progress. From the present study it is also noticed that though variable phenotypes are obtained in F_2 population, types close to the parents could also be obtained. A similar case of recovery of the original parental types was reported by Anderson (1936) in the genus *Apocynum*. In the present cross some *H. cannabinus*-like seggregates were recorded in F_2 population and a few of those plants have also combined the disease tolerance of the *H. radiatus* parent. All such plants were selected from the F_2 progenies and their performances in subsequent generations are being studied at present from disease resistance point of view.

Summary

In order to incorporate disease resistance character to *Hibiscus cannabinus* attempts were made to hybridize *H. cannabinus* ($2n = 36$) with 5 other disease resistant species of *Hibiscus*, *viz.*, *H. sabdariffa* ($2n = 72$), *H. radiatus* ($2n = 72$), *H. panduraeformis* ($2n = 24$), *H. lunariifolius* ($2n = 40$) and *H. vitifolius* ($2n = 34 \pm 1B$) and successful hybrids were obtained only from reciprocal crosses between *H. cannabinus* and *H. radiatus*.

The pollen fertility of F_1 hybrids in general was extremely poor as compared to the parents. Many characters in F_1 hybrids were intermediate, a few like *H. cannabinus* and others like *H. radiatus*.

Only 41 F_2 plants could be obtained. Of these, 17 plants were like *H. cannabinus*, 3 like the F_1 hybrids. The remaining 21 plants besides some parental characters (both *H. cannabinus* and *radiatus*) and F_1 characters also showed some peculiar and new morphological characters. No plant with completely *H. radiatus*-like characters could be obtained so far in F_2 population.

Due to extremely low population, the phenotypic classification of the F_2 families could not be made.

Acknowledgement

Our sincere thanks are due to Sri. N. Moitra for help during field-studies.

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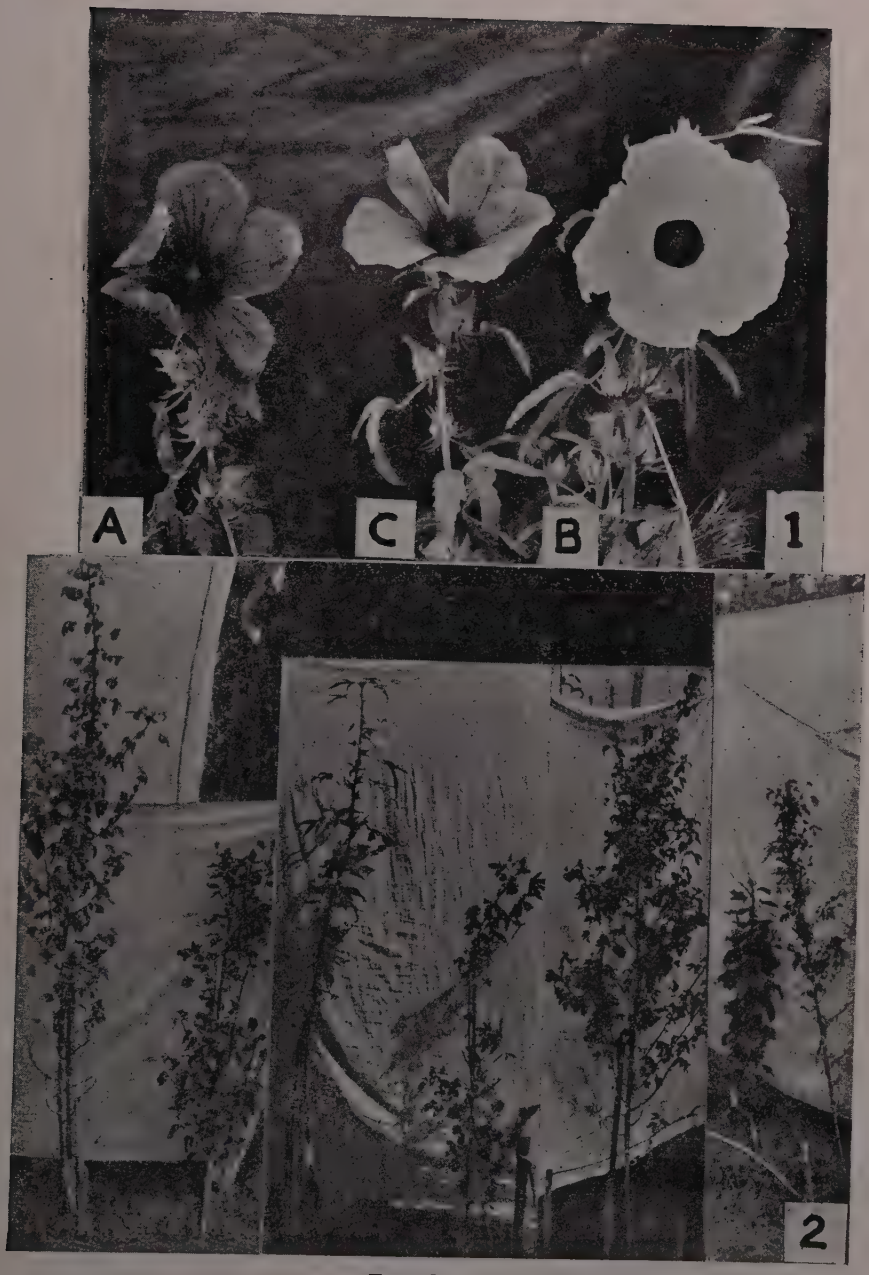
EXPLANATION OF PLATE XIV

FIG. 1. Parents and F_1 (*H. radiatus* × *H. cannabinus*) showing intermediate condition in size of flower, leaf, etc. (A. *H. radiatus*, B. *H. cannabinus*, C. F_1, *Ca*, × ¼).

FIG. 2. Some F_2 plants showing seggregated characters.



FIGS. 1–2

S. C. Rakshit *et al.*

A NEW SPECIES OF *PERICLADIUM* CAUSING STEM GALLS ON *GREWIA FLAVESCENS* JUSS.

By N. Prasad and R. N. S. Tyagi

Department of Agriculture, Government of Rajasthan, Udaipur

(Received for publication on May 8, 1960)

So far three species of *Pericladium*, viz., *P. piperii* on *Piper* from Transwal, *P. tiliacearum* on *Grewia tiliaefolia* and *G. rotundifolia* from South India and *P. grewiae* on *Grewia* (*mollis* ?) from Abyssinia, on *G. columnaris* from Ceylon, on *G. villosa* from North-Western Himalayas and on *G. orbiculata* from Ajmer, have been recorded (Sarwal, 1951).

In Rajasthan three species of *Grewia*, viz., *G. orbiculata* Rottl., *G. villosa* Wild. and *G. flavescens* Juss. growing on the foothills of Aravali ranges have been found to be infested with stem galls caused by *Pericladium* species. The bark of various species of *Grewia* is used for medicinal purposes. The fruits of *G. orbiculata* are also eaten with those of *Rhus mysorensis*. Since only one species of *Pericladium*, viz., *P. grewiae* causing stem galls on *G. orbiculata* have been reported from Ajmer (Rajasthan), studies on the causal organisms on three species of *Grewia* occurring in Rajasthan were taken up.

Morphology

Sori on stems of *G. orbiculata* and *G. villosa* are deep brown to dusty brown, crowded, angular pustules (1·5–3·5 mm.) which coalesce to form multilocular (2–5 locular) sori and are covered with a pubescent coriaceous indusium containing glutinous mass of chlamydospores when young, separating at maturity. "Witches Broom"-like symptoms are developed on the attacked branches of these hosts (Plate XV, Fig. 2).

Sori on stems of *G. flavescens* are light-coloured, sparsely distributed globose coalescing pustules (Plate XV, Fig. 1) having coarse and hairy indusium also containing glutinous mass of chlamydospores when young, which are separated at maturity. The sori are, however, larger (1·5–6 mm.) but are less crowded as compared to those of *G. villosa* and *G. orbiculata* and the "Witches Broom"-like symptoms are not observed (Plate XV, Fig. 3).

Germination of Spores

Germination of spores of *Pericladium* from *G. villosa*, *G. orbiculata* and *G. flavescens* was studied in water, solutions of glucose and sodium

chloride (from 0·1–0·9%) and on plain agar (from 0·1–0·9%). The spores germinated only in the solutions of glucose (from 0·3–0·8%) with maximum germination percentage in 0·5% glucose solution in 24 hours.

Further, the germination of spores from all the three hosts referred to above was studied in 0·5% glucose solution at 18° C., 20° C., 22° C., 25° C., 30° C., 35° C. and 37° C. It was observed that the optimum temperature for germination of spores from *G. villosa* and *G. orbiculata* was 25° C. and at 37° C. the spores did not germinate. The optimum temperature for the spores from *G. flavescens* to germinate was 18° C. while the spores ceased to germinate at temperature above 22° C.

In 0·5% glucose solution and at optimum temperature for germination of the spores from the three sources, the morphological differences in basidium and sporidium were noted. The basidia in case of *P. grewiae* (on *G. villosa* and *G. orbiculata*) were mostly straight and shorter (7·00–30·00 μ) in length as compared to those of *Pericladium* sp. on *G. flavescens* where they were longer (31·00–72·00 μ) and curved at several points (Plate XV, Figs. 4 and 5). The sporidia in case of *P. grewiae* (on *G. villosa* and *G. orbiculata*) were mostly elliptical often globose while in case of *Pericladium* sp. on *G. flavescens* they were mostly globose and rarely elliptical. In all the cases the sporidia were hyaline and of almost equal size (Plate XV, Figs. 4 and 5).

Germination of the chlamydospores of *P. grewiae* (on *G. villosa* and *G. orbiculata*) and of *Pericladium* sp. on *G. flavescens* from the material kept in the laboratory and that collected at intervals of four months from nature was studied in 0·5% glucose solution. It was observed that the chlamydospores of *P. grewiae* on both the species of *Grewia*, continued to be viable for a longer period (more than a year) than those of the fungus on *G. flavescens* which lost the viability after four months.

A comparison of the characters of the *Pericladium* species reported on these hosts is given in Table I. The smut on *G. flavescens* differs from *P. grewiae* (recorded on *G. villosa* and *G. orbiculata*) in the symptomatology, morphological characters of the sori and spores, in the temperature for the germination of spores, size and shape of basidium and shape of sporidium and is named as *Pericladium flavesci* Prasad and Tyagi sp. nov.

***Pericladium flavesci* Prasad and Tyagi sp. nov.**

Sori on twigs and stems, light brown in colour, sparsely distributed, globose coalescing pustules, enclosed by a coriaceous host tissue; sori with 2–5 locules due to confluence of pustules; 1·5–6 mm. in diameter. Spores globose, rarely angular, dark brown, 5·16–10·32 μ in diameter with an average of 6·17 μ, smooth intine thicker than exine, more or less agglutinated when young but separate from each other at maturity, germinating usually by means of uniseptate hyaline basidium with a

TABLE I

Characters of Pericladium *species from three species of* Grewia *in Rajasthan*

Sl. No.	Pathogen	Host	Sori		Size of the spores	
			Nature	Dehiscence	Range	Average
1	*P. grewiae* (Pass) Mund.	*G. villosa*	Deep brown, angular coalescing pustules with coriaceous indusium	Small slit	5·16–12·04 μ	8·60 μ
2	do.	*G. orbiculata*	Blister-like pustules often crowded and covered with coriaceous indusium	,,	5·16– 9·45 μ	6·88 μ
3	*P. flavesci* Prasad and Tyagi	*G. flavescens*	Light brown coalescing but sparsely distributed pustules and covered with coriaceous host tissue	,,	5·16–10·12 μ	6·17 μ

Sl. No.	Pathogen	Colour of the spores	Nature of the walls of spores	Germination of spores		Size of basidia	
				Optimum temperature	Range of temperature	Range	Average
1	*P. grewiae* (Pass) Mund.	Brown	Exine brown, intine hyaline both equal in thickness	25° C.	20–37° C.	7·18–30·00 μ	16·13 μ
2	do.	do.	do.	25° C.	20–37° C.	7·10–25·00 μ	13·5 μ
3	*P. flavesci* Prasad and Tyagi	Dark brown	Exine dark brown, intine hyaline and thicker than exine	18° C.	15–22° C.	30·96–71·84 μ	34·4 μ

single terminal light brown globose sporidium. The basidia are usually longer and curved at several points with an average length of 34·4 μ.

On living twigs and stems of *Grewiae flavescens* Juss., collected by J. Abraham, K. L. Kothari and R. N. S. Tyagi from Bagdara, Udaipur, in the State of Rajasthan on 6th November, 1958.

The type specimens have been deposited in Herb. Crypt. Ind. Orient., I.A.R.I., New Delhi (No. 27004) and C.M.I., Surrey, England (I.M.I. 80640).

Sori in culmis et ramulis, pallide brunnei, sparse distributi, globosi, coalescentes in pustulas, circumdati textibus plantae hospitis; sori 2–5-loculati ob confluentiam pustularum, 1·5–6 mm. diam. Sporae globose, raro angulares, fusce brunneae, 5·16–10·32 μ diam., medietate 6·17 μ, entino levi et crassiori quam exino, plus minusve aggregatae in statu juvenili, maturae vero ab alterutra distinctae, germinantes vulgo per basidium hyalinum uniseptatum, unico terminali pallide brunneo sporidio. Basidia vulgo longiora et curvata in partibus nonnullis, longitudine media 34·4 μ.

Typus lectus in culmis et ramulis viventibus *Grewiae flavescentis* a J. Abraham, K. L. Kothari and R. N. S. Tyagi ad Bagdara, Udaipur in Statu Rajasthan die 6 novembris anni 1958 et positus in Herb. Crypt. Ind. Orient., I.A.R.I., New Delhi sub numero 27004 et in I.M.I. Surrey in Anglia sub numero 80640.

Summary

The comparative morphological and spore germination studies of *Pericladium* species infecting the three species of *Grewia* (*G. orbiculata*, *G. villosa* and *G. flavescens*) have been made.

P. flavesci Prasad and Tyagi on *G. flavescens* has been recognised as a new species. Absence of 'Witches Broom'-like symptoms, presence of larger and sparsely distributed pustules, intine of spore thicker than exine, a lower optimum temperature for germination of spores and markedly longer basidia bearing mostly globose sporidia are the characters distinguishing the new species from *P. grewiae* earlier reported on the other two hosts.

Acknowledgement

Sincere thanks are due to Shri Samarth Raj, Director of Agriculture, Rajasthan, for facilities, to Prof. Dr. B. Tiagi for the identification of *G. flavescens* and to Rev. Father Dr. H. Santapau, St. Xavier's College, Bombay, for the Latin diagnosis.

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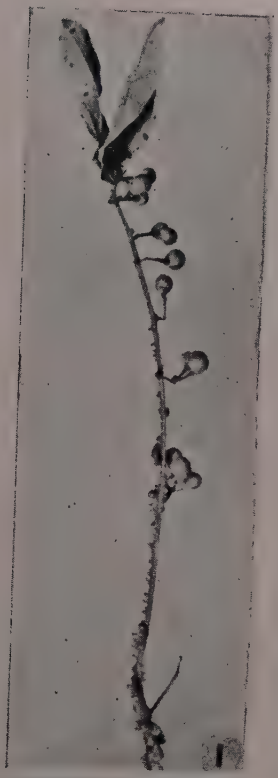
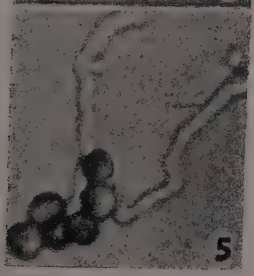




FIGS. 1–5

N. Prasad and R. N S. Tyagi

EXPLANATION OF PLATE XV

FIG. 1. Twig of *G. flavescens* with sparsely distributed sori.

FIG. 2. Twig of *G. orbiculata* with distinct 'Witches Broom'.

FIG. 3. Twig of *G. flavescens* lacking 'Witches Broom'.

FIG. 4. Germinating spores of *P. grewiae*.

FIG. 5. Germinating spores of *P. flavesci*.

MORPHOLOGY OF THE GAMETOPHYTE AND YOUNG SPOROPHYTE OF *MATTEUCCIA ORIENTALIS* (HK.) TREV.

By B. K. Nayar

National Botanic Gardens, Lucknow, India

(Received for publication on May 12, 1960)

Matteuccia Todaro (*Struthiopteris* Willd.) is a small genus of two recognised species (Copland, 1947), *M. struthiopteris* of Europe, E. Asia and E. N. America and *M. orientalis* of the Himalayas, ranging across China to Japan. Two others, *M. cavaleriana* and *M. japonica*, listed in Christensen's Index (1906–34) are regarded as geographical variations of *M. orientalis*. The genus has long been phylogenetically a problematical one: its affinity to *Onoclea* seems to be well established but "their collective affinity has been the subject of wide, not to say wild, speculations" (Copeland, 1947: p. 104). Bower (1928) and Christensen (1938) regard them as an offshoot of the Cyatheoid ferns, linking Cyatheaceae with the Blechnoids. Ching (1940) separates them as a family (Onocleaceae Ching) regarding them as an offshoot of the Cyatheoid-Aspidioid line of descent and closely allied to *Woodsia*, *Peranema* and *Diacalpe*. According to Copeland (1947) the Onocleoid ferns are closely related to *Woodsia*, *Peranema* and *Diacalpe* and along with them belong to his Aspidiaceae. He contends that they are not descended from Cyatheoid ferns, nor are they related to the Blechnoids. Holttum (1947) leaves the Onocleoid ferns, unplaced in his classification, pending further investigation. He, however, does not subscribe to Bower's view on their relationships. Recently, Pichi-Sermolli (1959) has suggested that the Aspidiaceous ferns have probably a Gleichenioid ancestry.

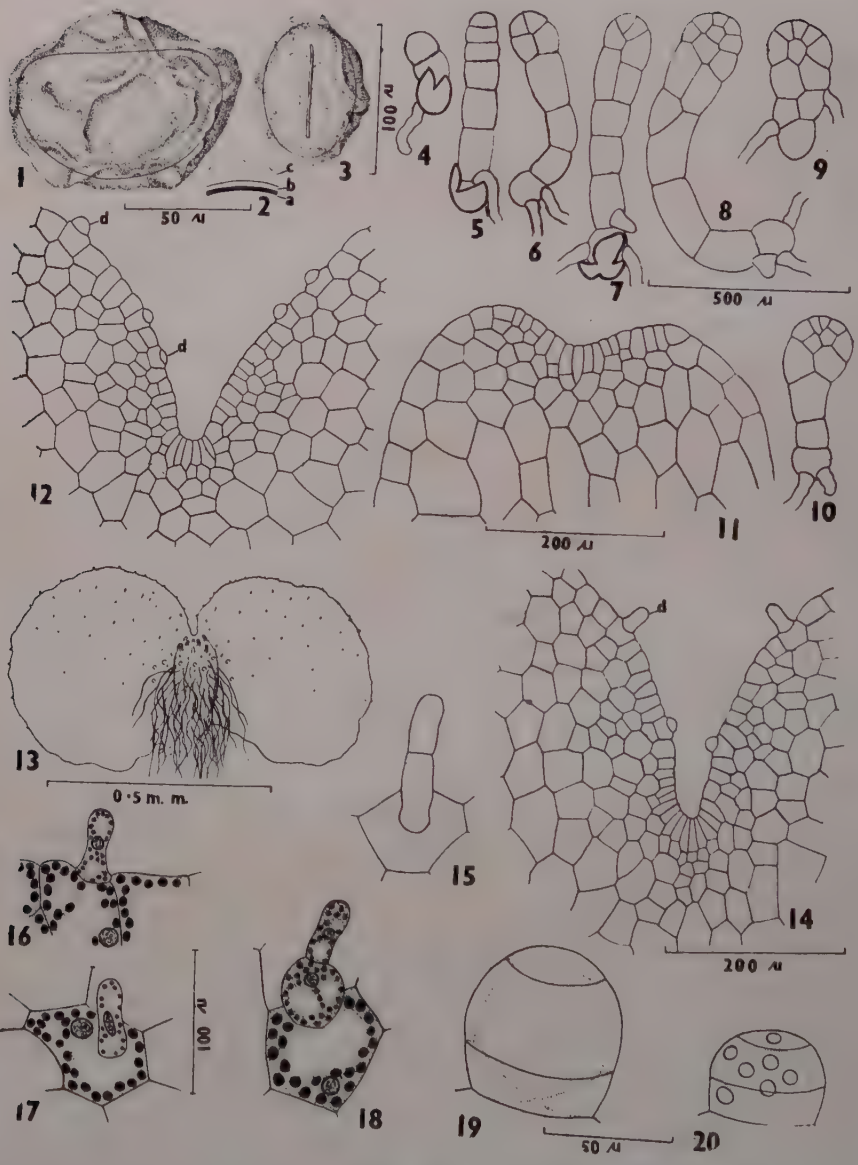
The present study is based on the Indian species *M. orientalis* (Hk.) Trev. The spores were collected successively in November, 1958 and 1959, from plants growing wild at Shillong Peak (1,600 m.) in Assam. Cultures were made a week after collection, in each case, on sterilised Knop's agar medium in glass containers, on well deteriorated sterilised moss in unglazed earthenware containers supplied with water from below (Nayar, 1960 *b*), on porous clay crock resting on deteriorated moss and on distilled water. All cultures were maintained in a well lighted shaded place in the laboratory at a temperature of 23–25° C. Morphology of the spore is studied from acetolysed preparations mounted in glycerine jelly (after the technique of Erdtman, 1951).

Spores

The spores of *M. orientalis* (Text-Figs. 1–3) are monolete (bilateral), with a prominent perine and measuring on an average $62 \times 97 \times 63\,\mu$ ($P \times E_1 \times E_2$, exclusive of perine). They vary from $48 \times 58 \times 50\,\mu$ to $70 \times 105 \times 66\,\mu$, the great majority of spores being of the average size. The exine is thin (Text-Fig. 2), smooth and enveloped by a folded, thin, transluscent and granulated (L.O. pattern) perine which extends upto $15\,\mu$ from the general surface of the exine. The laesura is thin and long (upto $80\,\mu$). Fresh spores are pale-brown in colour and contain yellowish oil globules and pale-green chloroplasts included in the cytoplasm. Structure of the spore in the genus is as described by Marengo (1956).

Prothalli

Germination occurred in two weeks in agar cultures and a few days later on other media. A few days before the emergence of the rhizoid, the spores swell and become deep-green possessing dense chloroplasts. The spore coat breaks at the laesura and the prothallial cell may protrude first or the rhizoid. The spore coat soon breaks irregularly and may be shed off. The prothallial cell grows out into a germ filament (Text-Fig. 4) and the basal cell often produces more rhizoids. The germ filament is several cells long (Text-Fig. 5) and under favourable growth conditions consists mostly of short barrel-shaped cells, the basal cell in all cases being hemispherical or often slightly bulbous (Text-Fig. 6). Under crowded conditions one or a few of the cells next to the basal cell may elongate and the development of the filament is slow. Branching and other abnormalities are not noted in cultures. Formation of a prothallial plate is initiated by longitudinal divisions of the anterior cells of the germ filament (Text-Fig. 6). The terminal cell usually divides longitudinally once or twice, followed by transverse divisions of the daughter cells, resulting in a spatulate thallus devoid of any specialised meristem (Text-Fig. 8). Rarely the terminal cell divides by two oblique walls at an angle to each other, establishing an obconical apical cell (Text-Fig. 7). Under favourable growth conditions the germ filaments may initiate plate formation when only three or four cells long and all the cells except the bulbous basal cell may divide longitudinally, resulting in a short obcuneate thallus (Text-Fig. 9). In all prothalli a wedge-shaped apical meristematic cell is developed sooner or later (Text-Fig. 10) and the cordate form is attained within two weeks of germination (Text-Fig. 11). The apical meristematic cell continues activity till the prothallus is distinctly cordate. It is replaced by a group of narrow meristematic cells, well after the prothallus becomes distinctly cordate with broad lateral wings and a central midrib bearing antheridia (Text-Fig. 12). The basal cell of the germ filament regularly bears one or more rhizoids. Rhizoids may be developed by other basal cells but there is no regularity in their position. The rhizoids are soft in texture and faintly brownish in colour. Superficial rhizoids are developed only when the prothallus becomes cordate.



Text-Figs. 1–20. Fig. 1. Lateral view of the spore. Fig. 2. Portion of spore wall, showing stratification. Fig. 3. Proximal view of the spore. Fig. 4. Spore germination. Fig. 5. Uniseriate germfilament. Figs. 6–9. Stages in the development of the prothallus, showing plate formation and diffused growth of the apical region. Fig. 10. Young prothallus, showing development of an apical meristematic cell. Fig. 11. Apical region of young prothallus, showing development of a cordate apex. Fig. 12. Apex of young cordate prothallus, showing

development of a multicellular meristem and formation of marginal hairs. Fig. 13. Fully grown prothallus (ventral view). Fig. 14. Apex of the same, showing cellular organisation. Fig. 15. A two-celled superficial hair. Fig. 16. Optical-section of a marginal hair and the subtending cell. Fig. 17. Same, of a unicellular superficial hair. Fig. 18. Same, of a superficial hair with a bulbous basal cell. Fig. 19. Mature antheridium. Fig. 20. Young antheridium. (*a*, endoexine; *b*, ectoexine; *c*, perine; *d*, hair.)

The mature prothallus (Text-Fig. 13) is cordate or more commonly reniform with the anterior margin deeply cleft into two, almost semi-circular lobes by an apical notch at the bottom of which the meristem is located (Text-Fig. 14). The thallus is usually 0·65 cm. broad and less than 0·5 cm. long. In cultures the prothallus attains maturity within ten weeks of germination of the spores. Antheridia are produced by three weeks old thalli. A midrib is developed within four weeks and archegonia are developed by thalli over five to seven weeks old. After archegonial formation the rate of growth of the thallus is slackened and after fertilisation, growth is almost arrested. The midrib is thin and in cultures did not attain more than five or six cells in thickness. The cells of the prothalli are uniformly thin-walled and densely chlorophyllous (Text-Figs. 17, 18).

The prothallus in the early stages of development is naked (Text-Figs. 4–11). Marginal and superficial hairs are developed sparsely as the prothallus becomes distinctly cordate (Text-Fig. 12) and towards maturity hairs are formed more profusely occurring on both the surfaces, on the wings and the midrib as well as on the margin. Marginal hairs are developed usually five to six cells away from the meristem and initiates as small lens-shaped cells cut off towards the centre of the mother cell. Full grown marginal hairs are unicellular and papillate or club-shaped and having slightly dilated bases. The prothallial cell bearing the hair may divide longitudinally, so that older hairs in some cases appear seated directly over the dividing wall. The hairs are uniformly thin-walled, with dense protoplasmic contents and one or two small vacuoles (Text-Fig. 16). The nucleus of the hair is comparatively smaller than the nuclei of adjoining prothallial cells and are often placed towards the middle of the hair. The hairs are chlorophyllous, and the chloroplastids are markedly smaller in size and paler in colour compared to the chloroplastids of the other prothallial cells. Superficial hairs may be of the same type as the marginal hairs (Text-Fig. 17) especially on young thalli. On old thalli many of them are two-celled (Text-Fig. 15), with the basal cell variously swollen, sometimes bulbous and with vacuolated contents (Text-Fig. 18). No extracellular secretions are observed either on the marginal or on the superficial hairs.

Antheridia (Text-Figs. 19, 20) are superficial, globular and of the usual structure and type of development in the 'Polypodiaceae' (Davie, 1951). The opercular cell is circular and undivided. The basal wall of the central cell often touches the basal wall of the stalk cell. No irregularities in the development and structure of the antheridia are noticed. The archegonium develops in the customary way. Archegonial neck is five to six cells long, consists of five or six tiers of short

cells and bends in all directions, most of them being curved towards the apical notch of the prothallus.

Young Sporophytes

Fertilisation is rather sparse under cultural conditions. The lamina of the first juvenile leaf is broadly obcuneate to almost semi-circular in outline. The outer margin is lobed almost half-way down the lamina into four main lobes, each with a slightly cordate apex. The single vascular bundle of the stipe forks into two, just before entering the lamina, the branches usually proceeding close to the margin of the leaf for a short distance after which they fork again, each branch vein entering one of the main lobes of the lamina. The extreme margin of the lamina is composed of a single row of large cells, each of which projects prominently out forming blunt teeth. These marginal cells are highly vacuolate and contain only very few chloroplasts. The stipe and the lower surface of the lamina bear sparsely distributed unicellular papillate hairs of the type described on the prothallus, but with small greenish-yellow cap-like extracellular secretions at the apex. The second leaf (or in rare cases the first leaf itself) develops a midrib. The apex is pronounced and the lamina becomes broadly ovate, with one median and a pair of lateral main lobes. Each lobe is forked towards the tip, the segments having cordate apices. The midrib appears as a direct continuation of the stipe bundle. A pair of lateral veins originates towards the apex of the stipe, where the stipe merges with the lamina. The lateral veins are opposite at origin and supply the lateral lobes of the lamina, each vein forking twice. In the succeeding leaves the midrib bears sub-opposite to alternate branches and the margin is correspondingly lobed. The lamina and the stipe of the second leaf bear papillate hairs as on the first leaf. Some of the hairs towards the base of the stipe are larger and three or four cells long, the terminal cell being club-shaped and with dense-brown contents. These hairs on the succeeding leaves develop into paleae.

Discussion

The prothallus of *Matteuccia struthiopteris* is described by Campbell (1895) and Lagerberg (1908) as cordate, naked and having the common type of development for advanced ferns, *i.e.*, by the formation of an apical meristematic cell from the terminal cell of the germ filament and its replacement later in development by a multicellular meristem. Stokey and Atkinson (1954) mention that the prothallus of *Onoclea sensibilis* is profusely hairy. The majority of gametophytes described for Copeland's Aspidiaceae are cordate and hairy, with the exception of *Elaphoglossum* (Stokey and Atkinson, 1957) and a scattered minority of species like *Didymochlaena sinuata* (Stokey and Atkinson, 1954), some species of *Athyrium* (Lagerberg, 1908) and *Matteuccia struthiopteris*. The hairy, cordate mature prothallus of *M. orientalis*, thus, conforms with the common type in Aspidiaceae. The simple papillate marginal hairs are some of the most common among the higher ferns, especially the Aspidiaceae.

As regards *Woodsia*, *Peranema* and *Diacalpe*, which are regarded as related to *Matteuccia* (Ching, 1940; Copeland, 1947), there is little detailed information regarding the morphology of the prothalli. The spores of these ferns are monolete and with prominent, folded perine. Schlumberger (1911) has reported the presence of multicellular hairs on the prothalli of *Woodsia* and *Diacalpe*. The prothalli of *Diacalpe aspidioides* and *Peranema cyatheoides* grown in this laboratory conforms with these observations. They are cordate, with marginal and superficial papillate hairs, some of the superficial ones being divided by septae. But these species differ from *M. orientalis* in that the terminal cell of the germ filament stops growth after some time, being in most cases terminated by a hair. A meristematic cell is then developed laterally. Also, in these ferns, marginal hairs are developed by the prothalli from very early stages of development onwards. A meristematic cell is also developed early, as is common in other Aspidiaceous ferns like *Polystichum*, *Dryopteris*, *Athyrium* (Nayar, 1960 *a*), etc.

The Onocleoid ferns are regarded by some pteridologists as forerunners of the Blechnoid ferns (Bower, 1928). Of the Blechnoids, the prothalli of *Blechnum* (Stokey and Atkinson, 1952 *b*; Nayar, 1961) are cordate, massive and with papillate hairs both on the margin and surfaces. The mode of development of the thallus in some species, like *B. brasiliense* and *B. spicant* is, however, apparently different, the apical cell of the germ filament in these cases often ending in a hair. But in *B. gibbum* the development of the thallus is more like that of *Matteuccia orientalis*, the prothallus becoming spatulate by diffused growth of the anterior region. A meristematic cell is developed later and then marginal hairs begin to be formed. In any case, the mature prothalli of *M. orientalis* are comparable to the prothalli of *B. orientale* and *B. gibbum*, though the latter are often much larger and heavier. Also, it is interesting to note that the two-celled superficial hairs, as found in *M. orientalis*, occur sometimes in *Blechnum* also. The antheridia of *B. brasiliense*, *B. spicant* and *B. buchtienii* are small and possess columnar basal cells while those of *B. gibbum* are large, comparable in size and structure to the antheridia of *M. orientalis*. The archegonium in *M. orientalis*, however, shows the primitive condition of having the neck curved towards the apex of the prothallus. Among other Blechnoid ferns the prothallus of *Stenochlaena* is reported to be almost similar to those of *B. spicant* and *B. brasiliense*. The development of the spathulate stage of the prothallus is even more lop-sided (Stokey and Atkinson, 1952 *a*). Also, the spores of *Stenochlaena* are reported to be devoid of perine whereas the spores of *Blechnum* possess a perine, in some species like *B. orientale* the perine being prominent. The gametophyte of *M. orientalis*, thus appears to have more in common with the gametophyte of *Blechnum* than that of *Stenochlaena*.

The Cyatheoid ferns, from which Bower (1928) traces the origin of *Matteuccia*, appear to be different from *M. orientalis* in gametophyte morphology. The spores of the Cyatheaceae are trilete and devoid of any perine. The prothalli (Stokey, 1930) also are not comparable in their mode of development and detailed morphology. The

characteristic scale-like multicellular hairs of the prothalli of the Cyatheaceae, arising from special wedge-like initials, appear to be significant and are without parallel in *Matteuccia*. As regards the Gleichenioid ferns, the spores of some species are monolete, but are reported to be devoid of perine and noticeably small in size (Stokey, 1950). In many species the formation of the prothallial plate begins by longitudinal divisions in the terminal cell of the germfilament and an apical meristematic cell is established only after the formation of a spatulate tip as in *M. orientalis*. Also, as in the latter, the young prothalli are naked, the hairs being formed only late in development. But the hairs, as in the Cyatheaceae, originate from special wedge-like initials and are superficial, being generally restricted to the archegonial region. The hairs are two-celled with large swollen terminal cells and short stalk cells (Stokey, 1950).

To sum up, it appears that the Cyatheaceae differ markedly from *M. orientalis* in the morphology of their spores and prothalli. As regards *Peranema* and *Diacalpe*, the mode of development of the prothalli is different, though the spores, the mature prothalli and the prothallial hairs are similar. To some extent the morphology of the gametophytes of the Gleicheniaceae resembles that of *M. orientalis*. But the Gleichenioids differ in their spores being devoid of perine, in the absence of marginal and superficial unicellular hairs and in the morphology and development of the superficial hairs. The spores and prothalli of some species of *Blechnum* seem to possess some features in common with those of *M. orientalis*, even though many species of *Blechnum* differ markedly. Also, it appears significant that *M. orientalis* differs from the other species of the genus, *M. struthiopteris*, in the development and morphology of the prothallus.

Summary

The spores of *Matteuccia orientalis* are large, monolete and with folded granulate perine and smooth exine. On germination the spore becomes deep-green and forms a germ filament which is several cells long and with a bulbous basal cell. The apex of the filament becomes spatulate by longitudinal divisions and diffused growth of the anterior cells including the terminal cell. Soon a wedge-shaped apical meristematic cell is formed and the prothallus becomes cordate. The meristematic cell persists long and is replaced by a multicellular meristem quite late in development. Prothalli in the early stages of development are naked. Unicellular papillate marginal hairs are developed by cordate thalli. Similar superficial hairs are formed after the formation of a midrib. Antheridia are large and of the usual type in the Polypodiaceae. The archegonial neck is curved towards the apex of the prothallus.

The first juvenile leaf is flabellate with a single vein which dichotomises twice. Unicellular, papillate, capped hairs occur sparsely on the lower surface of lamina and on the stipe. Usually the second

leaf develops a midrib, which appears as the direct continuation of the stipe bundle. Some of the hairs of the stipe are large, multicellular and with brown club-shaped apical cells.

The gametophytes are compared with those of the Cyatheaceae, the Gleicheniaceae, the Blechnoid ferns and some genera of the Aspidiaceae.

Acknowledgement

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THE CLASSICAL CONCEPT OF ANGIOSPERM CARPEL: A REASSESSMENT*

By V. Puri

School of Plant Morphology, Meerut, India †

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The so-called classical concept of the angiosperm carpel, like any other concept of plant morphology, has received much adverse criticism during the past 150 years or so it has been in existence. Some of this criticism is just and has enabled morphologists to modify the concept somewhat and to recognize its limitations and imperfections. If the concept has not been abandoned so far by many a morphologist it is not because it explains everything satisfactorily but because there is no other concept that can replace it for the entire group.

Some of the adverse criticism, however, is not warranted as it is based on findings that can still be explained, and perhaps better, in terms of the classical concept. Attention will be focused here on some recent assertions in this respect but before doing so it may be useful to state in a few words the essentials of the classical concept.

The so-called classical concept of the angiosperm carpel we owe to A. P. de Candolle who saw close *parallelism* or *equivalence* between a foliage leaf and a carpel. Subsequent authors elaborated it further so that in the current understanding, the carpel is envisaged as a leafy structure *involutely and adaxially folded on its midrib and bearing ovules on its margins*. This interpretation of the carpel morphology was based on studies of comparative morphology but subsequently it received substantial support also from anatomical studies (*see* Eames, 1931). It must, however, be pointed out that such an interpretation has no historical basis. It is just a way of resolving a carpel in terms of a foliage leaf; it should not be taken to mean that at any time in its evolution a carpel was necessarily an open leaf or it is derived from it.

Both the attributes of the carpellary leaf referred to above have been challenged during recent years on the basis of a detailed study of carpel structure in a number of primitive ranalian families; and

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† Research contribution No. 36 from the School of Plant Morphology, Meerut College, Meerut.

it has been suggested that the primitive ranalian carpel is a *conduplicately folded leaf, bearing ovules on its adaxial surface* and not on the margins. For the sake of convenience of description this view may be designated as *conduplicate concept*. It must, however, be emphasized that the two inferences involved are not complementary to each other. For instance, it cannot be argued that since the placentation in a particular case is laminar the carpel is necessarily conduplicately folded, or *vice versa*. A carpel with superficial placentation, as in the Nymphaeaceae, Butomaceae, etc., may still have evolved through involution of its margins as is envisaged in the classical concept. It is, therefore, necessary that both of these inferences should be substantiated by facts separately—a point that has perhaps not been adequately appreciated so far.

Support for the conduplicate concept is derived from the following considerations:

(1) The location of placentae on the supposed adaxial side of the megasporophyll, and not on its margin.

(2) The vascularization of ovules from both the ventral and dorsal systems of carpellary bundles.

(3) The *apparent* similarity of very young carpels, carpellodes and styles with a conduplicately folded foliage leaf.

More recently Periasamy and Swamy (1956) have offered some additional ontogenetic evidence in support of this concept. They assert that in the anonaceous *Cananga odorata* the marginal meristems of the carpellary primordium mature even earlier than the differentiation of placentae. This led them to suggest that in the carpel of this species "laminal differentiation attains normal completion before the inception of the placental ridges". Such a situation according to them "negates the possibility of an assumption of involute margins" as is assumed by the supporters of the classical concept.

Another point which Periasamy and Swamy have brought out is that "the ovules are vascularized by branches of the dorsal strand" and not by the ventral bundles even though the latter are much nearer to the placentae. This, according to them, is proof of laminar placentation and is believed to support the conduplicate concept.

A critical examination of all the arguments reveals that the data presented in support of the conduplicate concept admit of yet another interpretation which appears to be more in accord with the known facts and which is also in conformity with the so-called classical interpretation of the carpel (*cf.* Puri, 1955, 1959). It will, therefore, be desirable to discuss these points at some length here.

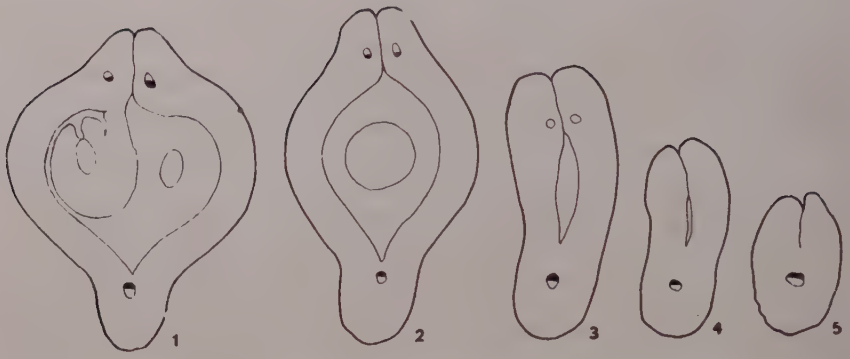
The location of the placentae.—The location of placentae, whether marginal or laminar, is an important point in any consideration of the nature of carpel. Bailey and Smith (1942) suggest that the margins of carpels in *Degeneria* are not infolded or coherent during ontogeny,

but tend to flare apart externally. They further assert that the placentation in this species is clearly laminar and that at anthesis, "broad areas (between margins and the placentae) of the adaxial surface of the megasporophyll are closely approximated", as they do in conduplicate leaves. No evidence seems to have been given for interpreting the surfaces, which stand face to face, as the ventral surface of the carpellary leaf.

The present author, however, is inclined to think that in arriving at such a conclusion the structure and magnitude of carpellary margins have not been adequately assessed. What have been described as margins are in fact only parts of margins. Margins of carpels, unlike those of a foliage leaf, are generally well developed and have prominent vascular supplies (*cf.* Thomas, 1931; Arber, 1931; etc.). They may be as thick as, or sometimes even thicker than, the main body of the carpel (*cf.* condition in Leguminosae, Ranunculaceae, etc.). Being generally so well developed they can be distinguished to have: (1) an *outer face*, frequently a part of the dorsal surface; (2) an *inner face*, a part of the ventral surface that is usually fertile and bears ovules; and (3) a *lateral face* that represents thickness of the margins and is involved in fusion of margins whenever it occurs. The occurrence of a more or less distinct *lateral face*, that is usually sterile, is an important structural feature that seems to have been completely ignored or misinterpreted so far in a discussion of carpel morphology.

It appears to us that in the formulation and elaboration of the conduplicate concept, this lateral face of the carpellary margins has been mistaken for ventral surface of the carpel, and on that account the placentae are described as laminar instead of marginal. That this is so seems to be borne out by a consideration of the orientation of the ventral bundles of carpels and of the funiculi of ovules. It is common knowledge that in a carpel, as also in a foliage leaf, the *ventral (marginal) bundle in transverse section always stands parallel to the lateral face, xylem and phloem being in line with it, and at right angles to the ventral surface. The funiculi of ovules also show the same orientation* (*cf.* Text-Figs. 22–24). These features, which have been observed by the author in a large number of families including Ranunculaceae (Text-Figs. 1–9), Anonaceae, Magnoliaceae (Text-Figs. 10–11), Rosaceae, Crassulaceae, Leguminosae (Text-Figs. 12–16), etc., appear to be sound architectural criteria for distinguishing the *lateral face* from the *ventral surface*.

If we apply these tests to the illustrations of Periasamy and Swamy (1956), Bailey and Nast (1943) and Bailey and Smith (1942) we find that the surface in question is actually the lateral face of the carpellary margins as the ventral bundle stands parallel to it and the funiculus in line with it rather than at right angles, as it is to the ventral surface. The condition in *Cananga odorata* is very clear in so far as the orientation of the ventral bundles and the ovules is concerned (*cf.* Text-Fig. 17). The same is the condition in certain species of *Drimys* (Text-Fig. 18). In *Degeneria*, however, the lateral face of the carpellary



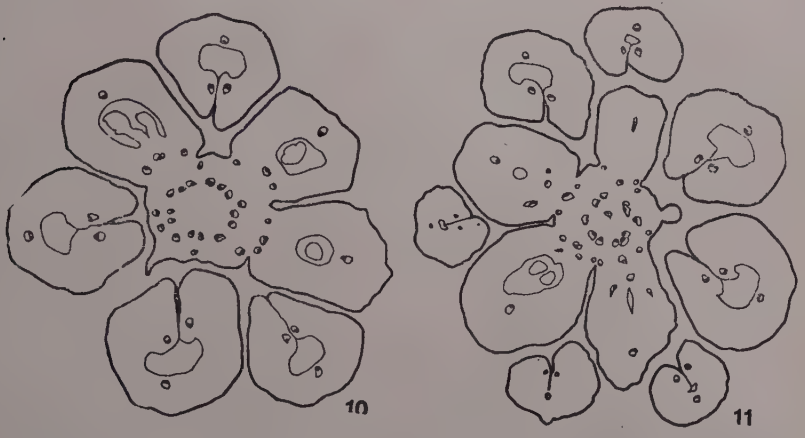
TEXT-FIGS. 1–5. T.S. of carpel of *Caltha palustris* from base upward, the lateral faces being closely appressed.

TEXT-FIGS. 6–9. T.S. of carpel of *Paeonia emodi* from base upward. Note the ventral bundles oriented parallel to the surface of the lateral face.

margins has become rather extensive and tends to flare apart externally forming a crest-shaped stigma (Text-Fig. 19). But there is little doubt that the situation is basically the same as in the last two species. Thus by accepting the concept of *lateral face* the ovules in all these cases can be interpreted as borne marginally and not superficially as suggested by the authors of the conduplicate concept.

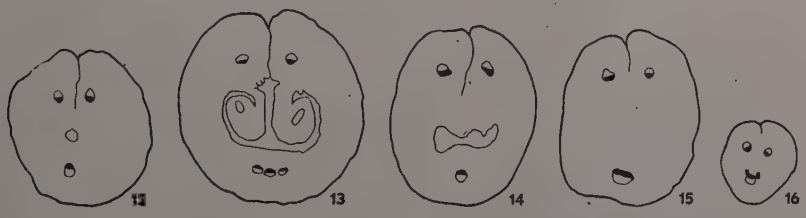
Vascularization of ovules.—As a rule, ovules receive their vascular supply from the ventral bundles or their fusion products, the placental strands (*see* Puri, 1952). Supporters of the classical concept of the carpel consider it as an important structural feature which ordinarily indicates the marginal (or sub-marginal) position of the placentae. In some cases, however, as in certain species of the Winteraceae (Bailey and Nast, 1943), Nymphaeaceae (Saunders, 1936), etc., dorsal bundles also have been known to contribute ovular traces. This has been cited as an evidence supporting the contention that the placentae are superficial on the ventral side and not marginal. True that in some cases as in the Nymphaeaceae, Butomaceae, etc., placentation is laminar rather than marginal and that the supporters of the classical concept of the carpel find it difficult to offer a satisfactory explanation

of it (*see* Puri, 1952; Parkin, 1955). But, as has already been stated, this fact does not lend any support whatsoever to *conduplicate folding* of the carpel.



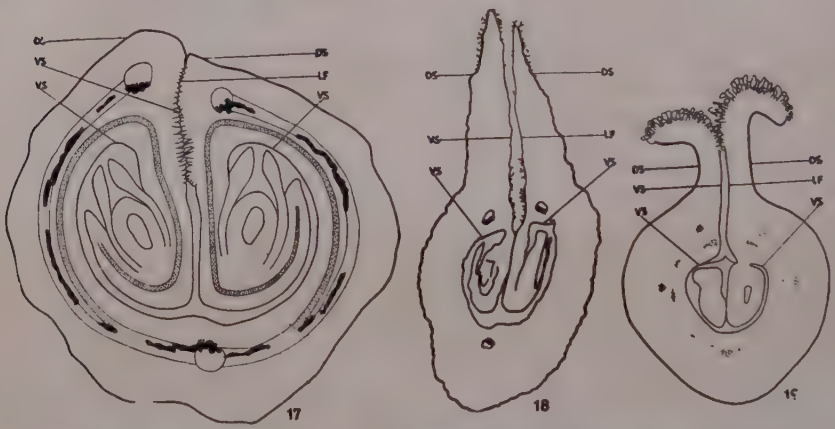
TEXT-FIGS. 10–11. T.S. of young gynoecium of *Michelia* sp. from base upward. The 'solid' style in the lower side in Fig. 11 gives the false impression of conduplicate folding.

Periasamy and Swamy (1956) have brought out a very interesting situation in *Cananga odorata* where although the ventral bundles occur very close to the placentae yet they do not furnish any ovular traces directly. It is, on the other hand, the dorsal bundle, situated quite far away on the opposite side, that gives off branches which divide into ovular traces. This means that in this species ovules receive their vascular supply from bundles farther away from them and not from those which are nearer to them. Such a situation renders the vascular bundles obviously ineffective, unless, of course, we believe in migration of the ovules from dorsal position to marginal position, in determining the position of the ovules, for even if the ovules were marginal they would still get their vascular supply from the dorsal bundle irrespective of their position.



TEXT-FIGS. 12–16. T.S. of carpel of *Acacia arabica* from base upward showing orientation of the ventral bundles and the ovules.

The form of young carpels, carpellodes and styles.—In some cases very young carpels, carpellodes and styles, in transverse sections, appear to assume a form which is very similar to conduplicate folding. All such cases have been used to support the conduplicate concept. It is stated, for instance, that "During the earlier stages of the ontogenetic development of primitive carpels (as of conduplicate leaves) the sides of the folded lamina, as seen in transverse sections, are approximately parallel" (Bailey and Swamy, 1951). It is also asserted that "in the sterile carpels of male flowers of Lardizabalaceae and other families this unmodified conduplicate form may be retained at anthesis." Further on, certain styles, in transverse section, are also described to show conduplicate folding.

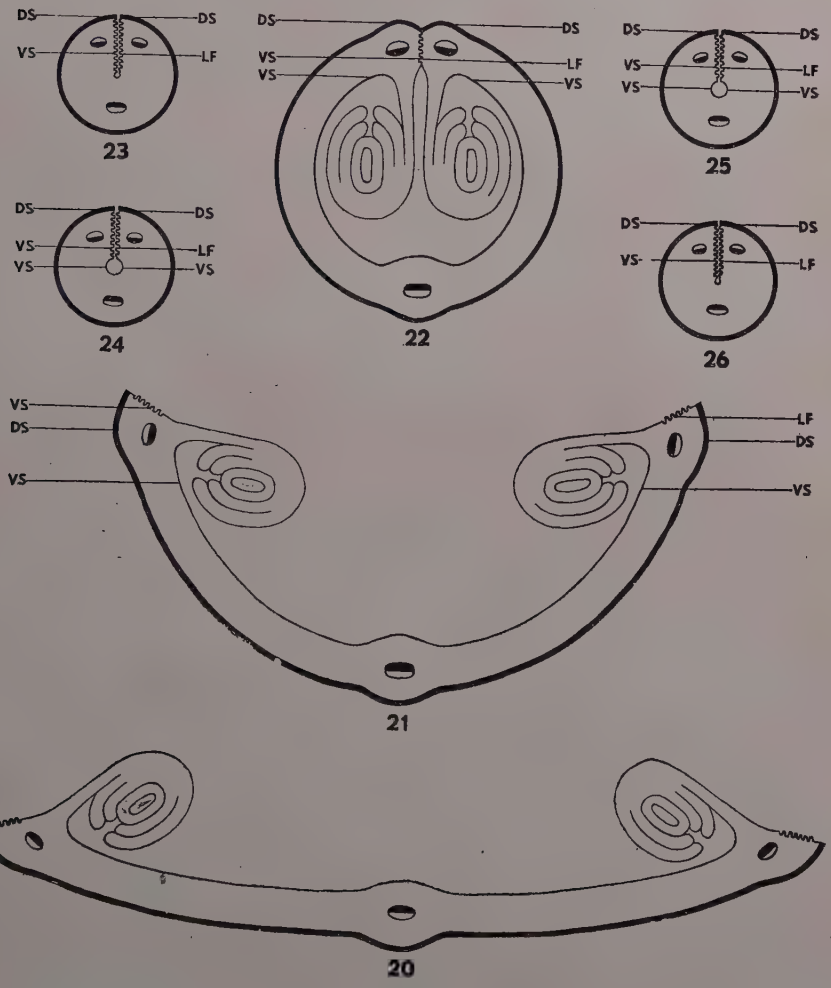


TEXT-FIG. 17–19. T.S. of carpel of *Cananga odorata* (modified after Periasamy and Swamy, 1956). Fig. 18. Same of *Drimys granadensis* (modified after Bailey and Nast, 1943). Fig. 19. Same of *Degeneria vitiensis* (modified after Bailey and Smith, 1942). Their explanation according to the present author is given on the right and that according to conduplicate concept on the left.

(DS = Dorsl snrfade; VS = Ventral surface; LF = Lateral face.)

The present author is inclined to think that these instances can be interpreted in a different way. It appears to him that these are cases in which the *functional* ventral surface which encloses the locule has not yet developed, as in very young carpels and carpellodes (*cf.* Fig. 23), or it has become more or less obliterated along with the locule, as in 'solid' styles (Text-Fig. 26). What has been interpreted as ventral surface in such cases is, according to the present author, the lateral face of the carpellary margins which have been brought together as a result of *involution* (*cf.* Text-Figs. 20–22 and 24–25). Such a suggestion, beside getting support from the orientation of the ventral bundles, is also borne out by the fact that the carpel and all its parts, as a general rule, follow a centripetal mode of development. In a young primordium of a closed carpel the first thing to differentiate is the dorsal surface covering a peg-like outgrowth, then the lateral faces of the carpellary margins and finally the inner ventral surface

with placentae and ovules. Such a sequence of events is very clearly seen in the numerous photomicrographs of cross-sections of young carpels reproduced by Grégoire (1938). Illustrations of Tepfer (1953), Periasamy and Swamy (1956) and Tucker (1959) also show the same thing, although these authors have interpreted them differently.



TEXT-FIGS. 20–26. Schematic representation to illustrate the difference of opinion between the present author (right side legend) and the supporters of conduplicate concept (left side legend). Fig. 23. Diagrammatic representation of a T.S. of young carpel in 'solid' state showing differentiation of lateral face. Fig. 24. Shows a later stage of the same with differentiation of locule. Figs. 25–26. Diagrammatic representation of transverse sections showing solidification of style. The appearances in Figs. 23 and 26 have been erroneously interpreted as representing conduplicate folding, the condition actually having been obtained through involution and solidification. In Text-Figs. 23–24 young and old stages have been overlapped together for convenience.

(DS = Dorsal surface; VS = Ventral surface; LF = Lateral face.)

Similarly in a sterile carpel, if there is no locule, and consequently no functional ventral surface, the adjacent lateral faces of the carpellary margins, if they are free, give the false appearance of conduplicate folding. Styles also may present the same deceptive appearance in transverse section after they have lost the locule and the functional ventral surface (Text-Fig. 26). Like a very young carpel or a carpellode they are solid inasmuch as they lack locules and the functional ventral surface. The occurrence of solid[1] young carpels, solid[1] carpellodes and solid[1] styles, therefore, does not lend any support to conduplicate folding, rather it supports the concept of involute folding of the carpellary margins.

More recently Periasamy and Swamy (1956) have cited some ontogenetic evidence in support of the conduplicate concept. This evidence in our understanding is conditioned by a basic assumption that the margins represent the last products of the marginal meristem. While this is largely so it is not all truth, for in cases where the margins are thick and well developed certain parts of them, particularly their outer edges, may show marginal activity for longer periods. Obviously these outer edges will be the last products of the marginal meristems and they are not equal to the whole margins.

Carpel primordium of *Cananga odorata*, according to Periasamy and Swamy, arises as a peg-like projection which appears as a solid structure in transverse section. Somewhat later, marked activity of the two masses of marginal meristems along the adaxial side "brings about the formation of a median longitudinal furrow" which deepens further. This stage, which is marked by the cessation of activity of the marginal meristem, is believed to indicate completion of laminal differentiation of the carpel. Since this is attained before the inception of placental ridges, it is asserted that it rules out any suggestion of involution of carpellary margins.

The present author believes that in these early stages the lateral faces of the carpellary margins have been misinterpreted as ventral surface of the carpel. The longitudinal furrow referred to above is actually formed by these lateral faces only and not by adaxial (ventral) surface of the carpel as is suggested by Periasamy and Swamy. These have been brought together through the so-called pytogenetic involution. The orientation of the ventral bundles and of the funiculi of the ovules bear strong testimony to such an inference. Thus the ontogenetic data recorded by Periasamy and Swamy appear to be satisfactorily explained in terms of the classical concept and there appears to be no necessity of propounding a new concept.

A natural corollary of the conduplicate concept is that the primitive stigma is believed to be crest-shaped extending laterally along the whole length of the ovary as in *Drimys piperita*. The present author is inclined

[1] This term refers to the condition lacking locule. Miss E. R. Saunders used the same expression in a different sense.

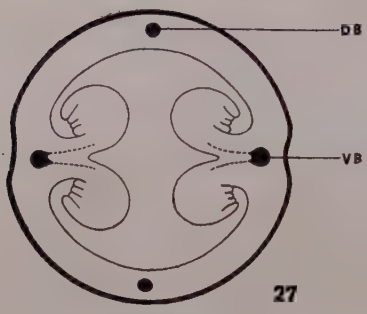
to suggest that in the primitive Ranales there might have been several attempts, in different directions, towards the formation of a stigma for receiving the pollen. Only one of these attempts, which resulted in a terminal stigma, was successful, while the others must have been more or less abortive. One such abortive attempt, if the author be permitted to indulge in such a speculation, may have been towards the formation of a crest-shaped stigma. Here the lateral faces of the carpellary margins might have extended outward quite extensively. This appears to be a more plausible interpretation of the conditions seen in *Degeneria*, *Drimys* and others, and following this the crest-shaped stigma in these species no longer remains a primitive structure but it represents the culmination of an evolutionary line that perhaps ended blindly, being apparently not very successful.

This brief analysis of the conduplicate concept reveals that the case of condupulicate folding is far from being proved. The data used to support this can still be explained, and perhaps more satisfactorily, on the basis of the classical concept of the carpel. Besides, a carpel is essentially an ovule-bearing organ and it is difficult for us to visualize how such a structure could show conduplicate folding in its ontogeny, unless of course we assume that ovule-bearing for carpels is a secondary innovation. In fact we cannot justifiably designate the structure as carpel before the inception of ovule.

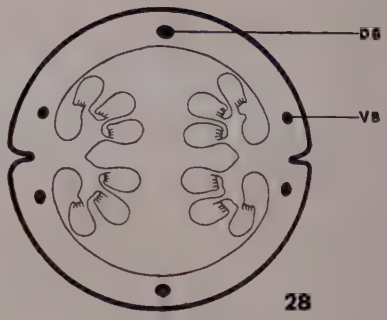
Regarding laminar placentation, it has been generally admitted that it occurs in a few cases, *e.g.*, Nymphaeaceae, Butomaceae, etc., and that it has not been satisfactorily explained so far by the supporters of the classical concept (*cf.* Parkin, 1955). But the cases cited by the exponents of the conduplicate concept do not, in the opinion of the author, conform to this type. *Degeneria*, *Drimys*, *Cananga*, etc., all seem to have marginally attached ovules, and have already been satisfactorily explained on the basis of the classical concept of carpel. In these cases the ovules *appear* to be superficial only because the surface representing the thickness of the carpellary margins has been mis-interpreted as the ventral surface of the carpel.

As pointed out earlier, the supporters of the classical concept do not have any clear insight into superficial placentation. The present author has, however, suggested tentatively that it may be a function of unequal extension of the ventral surface of the carpellary margins and that of the rest of the carpellary leaf (Puri, 1960). Such an explanation gets support from the condition prevalent in certain members of the Gentianaceae, Orobanchaceae, etc., where half-placentae separate apart from their counterparts due to extension of the intervening regions of the carpellary margins (Text-Figs. 27–32). Thus conceived the superficial placentation renders itself easily explicable.

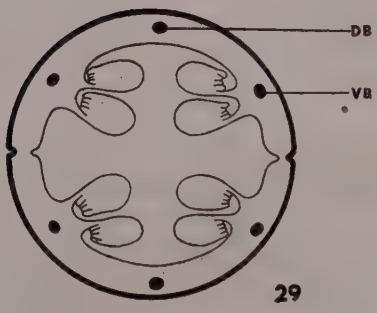
Professor W. Troll and his co-workers have brought to bear voluminous literature on the morphology of the carpel. Their work (Troll, 1939; Sprotte, 1940; etc.), is essentially ontogenetic and recognizes three forms of carpels: (1) *peltate* carpels with *manifest* peltation;



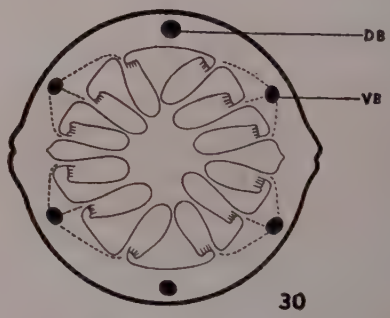
L. CRISTATUM



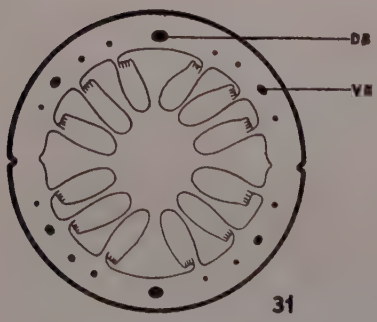
E. RAMOSISSIMA



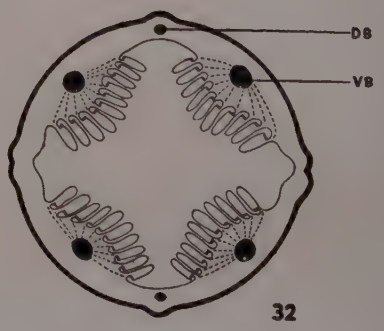
S. PANICULATA



G. PEDECILLATA



G. APRICA



G. CONTORTA

TEXT-FIGS. 27–32. T.S. of ovaries of certain genera (*Limnanthemum*, *Erythrea*, *Swertia* and *Gentiana*) of the gentianaceae showing gradual separation of half-placentae from their counterparts. By imagining an excessive extension of the marginal

regions that are fertile, and non-extension of the midrib regions that are sterile, one can visualize how the condition of superficial placentation could have been obtained.

(DB = Dorsal Bundle; VS = Ventral strand.)

(2) those with *latent* peltation and (3) those without any peltation or *epeltate*.

Carpels with manifest peltation have long stalks and ascidiform lamina whose free margins bear stigmatic papillae almost to the base (*e.g.*, *Thalictrum*). Like the petiole, the stalk has unifacial anatomy and develops in ontogeny after the upper part of the lamina has appeared. The transition zone between the stalk and the lamina develops into what has been called the "cross-zone" (Querzone), which also takes part in the formation of the ascidium and in bearing ovules.

Carpels with latent peltation are comparable to leaves which show peltation in embryonic condition but not at maturity. A stalk may be present as in *Eranthus* or lacking, as in *Consolida ajacis* which has sessile carpels.

The epeltate carpels are characterized by complete absence of peltation at any stage of their development. They are horse-shoe-shaped from the very beginning and do not show any fusion of their margins at the base. They are believed to have been derived from peltate carpels through suppression of the "cross-zone" and the stalk.

Professor Troll and his school consider that in the mode of initiation, development, location and vasculature the carpels are essentially similar to foliage leaves. Their approach (*Gestalt*, as it is commonly known) to carpel morphology is inclusive, rather than exclusive, with the classical concept. The only difference, as we see it, is that they go only so far as their ontogenetic observations take them. In other words they are more realistic and less idealistic than a classical morphologist who goes further beyond to visualize to understand a peltate structure in terms of his *type* to which all the different forms are referable.

Thus conceived the involute carpels and the peltate carpels are not different types but different forms of the same type representing different lines of specialization. Just as a peltate leaf can be vaisualized in terms of an ordinary leaf, so also a peltate carpel.

An apparently very powerful attack on the classical concept of angiosperm carpel comes from Grégoire (1938) who asserts that the foliage leaf and the carpel are two morphologically irreducible categories or two distinct morphological types which are fundamentally different from one another. His view, which has been described as *sui generis* view, has been the subject of several excellent reviews during recent years (*see* Tepfer, 1953; Joshi, 1947; and the work of Professor Troll and his school). Without going into details of the subject, therefore, it may be pointed out that Grégoire was rather hasty in his conclusion and overemphasized the differences that he observed in

the morphogenesis of leaf and carpel. These differences according to most morphologists are differences of degree rather than of kind and are explicable in terms of their functional requirements.

The relationship between the carpel and the ovule is perhaps a most controversial aspect of carpel morphology. According to the classical concept the ovule is considered as a part and parcel of the carpel, being borne on its margin. But ever since the time of Schleiden (1849) someone has always believed that the ovules are axial structures and that the carpels just form sterile envelopes for them (*e.g.*, Hagerup, 1938, 1939; Barnard, 1957 *a*, 1957 *b*, 1958; Moeliono, 1959; etc.). Free central and basal placentations seem to fit in well with such a concept. But an obvious difficulty is experienced in dealing with parietal placentation. Hence some authors (*e.g.*, Lam, 1948) recognize both axial (Stachyospory) and carpellary (Phyllospory) ovules. Some others (*e.g.*, Hagerup, 1939) have explained the parietal placentation as a condition in which the central axial column bearing ovules splits into a number of segments that become fused parietally with the ovary wall, much in the same manner as the epipetalous stamens. Apparently Hagerup does not admit of any phyllosporous condition.

This view of treating the ovule as an independent structure does not get any support from anatomy. The placenta on which the ovules are borne is invariably a double structure, being composed of two halves (*see* Puri, 1952)—a fact borne out by its often clefted nature, double vascular supply and orientation of its ovules in two opposite directions (*see* Text-Figs. 27–32). If the placenta were equivalent to a stamen it should not have been a double structure.

In a brief but very thought-provoking article Fagerlind (1958) has focused pointed attention on this problem. I recognize with him the limitations of ontogenetic studies but I do not see any equivalence between the primordia of a carpel and its associated ovule on the one hand and that of a foliage leaf and its axillant branch on the other. No doubt in longitudinal sections, with which Fagerlind is dealing, the primordia of an ovule and of a vegetative axillary branch look very much alike. But it is not difficult to see that the ovule is seldom situated in a truly axillant position—opposite the midrib; most frequently in open carpels with parietal placentation it corresponds in position with the carpellary margin. In closed carpels too its position is quite different from that of an axillant branch. So I do not see much in common between the ovule-bearing placenta of angiosperm and an axillary branch of a vegetative shoot or for that matter the ovuliferous scale of gymnosperms. The position of the placenta, like its anatomy, is better explained on the basis of the classical concept.

Thus broadly speaking the classical concept of the angiosperm carpel still holds good and serves as a 'useful instrument of description'. It has the advantage of being simple and yet applicable to all the groups of angiosperms. As long as facts can be explained on this basis we would not like to accept any other interpretation.

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EMBRYOLOGICAL STUDIES IN ACANTHACEAE

IV. Development of Embryo-sac and Seed Formation in *Haplanthus tentaculatus* Nees

By V. G. Phatak* and (Miss) K. B. Ambegaokar

Department of Botany, M.S. University of Baroda, Baroda

(Received for publication on May 12, 1960)

Introduction and Previous Literature

The early investigations on the embryology of Acanthaceae have been reviewed by the authors in their previous papers (Phatak and Ambegaokar, 1956 and 1957), and by Johri and Hardev Singh (1959).

The present paper deals with another member of Acanthaceae, *Haplanthus tentaculatus* which belongs to Acanthoideae-Imbricatae-Andrographideae of Engler and Prantl (1897) and to Justicieae-Andrographideae of Hooker (1885).

A few cursory observations on the embryology of *Andrographis ehioides* Nees have been made up by Mauritzon (1934) and he suggested transposition of the subtribe Andrographideae to the tribe Thunbergioideae. To investigate this point it was felt that the subtribe Andrographideae should be further studied and hence the present study dealing with the development of embry-sac and seed formation in *Haplanthus tentaculatus*.

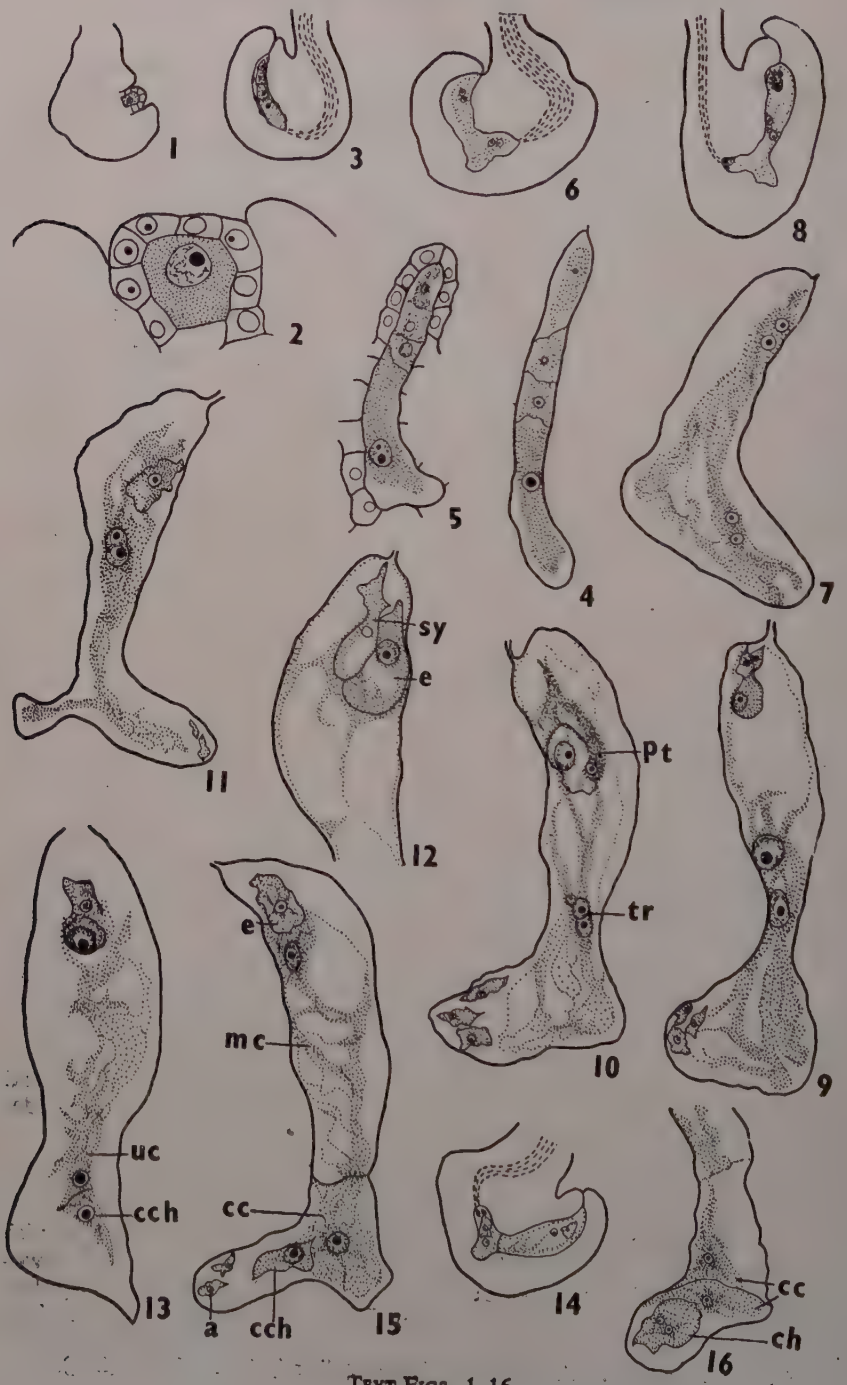
Material and Method

Haplanthus tentaculatus Nees is a herbaceous plant with glandular pubescent stem bearing cladodes. The material was fixed in formalin-acetic-alcohol and was stored in 70% alcohol. The usual methods were followed for dehydration and sections were cut 5–7 microns thick and were stained with Heidenhain's iron-haematoxylin. They were destained with picric acid.

Observations

The flowers are borne in axils. The bi-lipped corolla is greenish white with dark lilac lines. The stamens are two and anthers are two-celled. One of the anther-lobes is bearded at the back and the pollen grains are of 'Daubenpollen' type of Engler and Prantl (1897). The

* Present address: College of Science, Adhamiyah, Baghdad (Iraq).



TEXT-FIGS. 1–16

TEXT-FIGS. 1–16. *Haplanthus tentaculatus* Nees. Figs. 1, 3, 6 and 8. Curvature of embryo-sac. Fig. 2. Micropylar part showing the hypodermal megaspore mother cell. Fig. 4. Linear tetrad. Fig. 5. The upper two megaspores in degeneration. Fig. 7. 4-Nucleate embryo-sac. Fig. 9. Mature embryo-sac. Fig. 10. Fertilization and triple fusion. Fig. 11. Fertilized embryo-sac showing zygote and primary endosperm nucleus. Fig. 12. Micropylar part of the embryo-sac showing zygote and hypertrophied synergid. Fig. 13. Embryo-sac with larger upper chamber and smaller chalazal chamber. Fig. 14. L.S. of ovule at stage as in Fig. 15 (Diagrammatic). Fig. 15. Endosperm showing micropylar, central and chalazal chamber. Fig. 16. Chalazal part of the embryo-sac showing 2-celled central chamber and 2-nucleate chalazal haustorium.

(*e*, zygote; *sy*, synergid; *tr*, triple fusion; *pt*, pollen tube; *uc*, upper chamber; *chh*, chalazal chamber; *a*, antipodal cell; *ch*, chalazal haustorium; *cc*, central chamber; *mc*, micropylar chamber; *mh*, micropylar haustorium.)

(Figs. 1, 3, 6, 8 and 14, × 100. Figs. 2, 4, 5 and 7, × 590. Figs. 9, 10, 11, 12, 13, 15 and 16, × 420.)

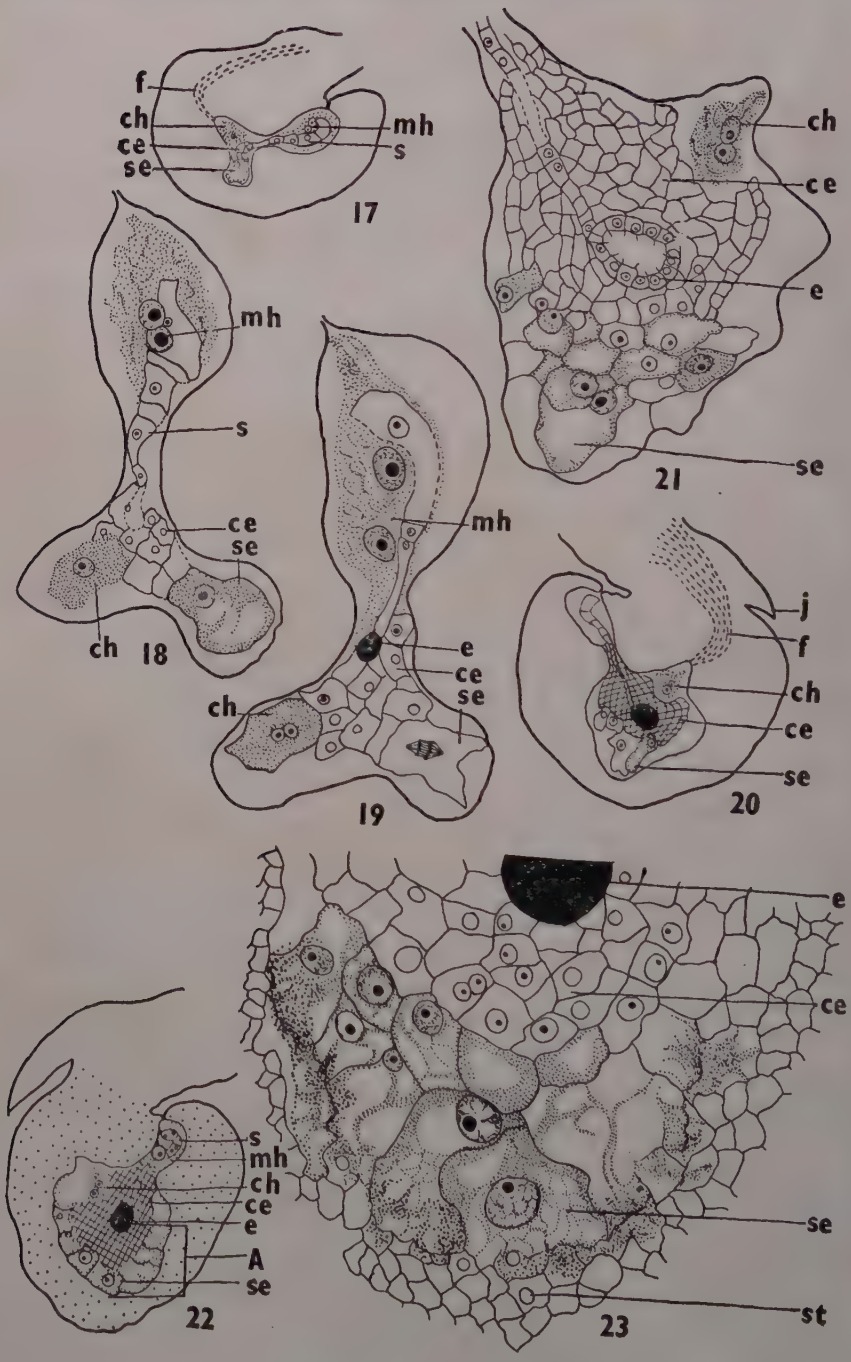
ovary is bicarpellary with four ovules in each cell borne on an axile placenta. The mature fruit is an 8-seeded capsule and is compressed at right angles to the septum.

Megasporogenesis and female gametophyte.—The ovules here are unitegmic and tenuinucellate. A single massive integument appears soon after the differentiation of the archesporial initial in the hypodermal layer and grows rapidly to form a narrow micropyle (Text-Fig. 8). The ovule gets curved, and at the tetrad stage, it becomes campylotropous (Text-Fig. 3). A single-layered nucellus persists upto tetrad stage (Text-Fig. 5) and then degenerates. The vascular supply reaches upto chalazal end of the embryo-sac.

The hypodermal archesporial cell functions directly as the megaspore mother cell (Text-Fig. 2). The megaspore mother cell undergoes meiotic divisions to form a linear tetrad of megaspores (Text-Fig. 4) out of which the chalazal one is functional (Text-Fig. 5). The chalazal megaspore by 3 successive divisions forms an 8-nucleate 'Polygonum' type of embryo-sac (Text-Fig. 9). During the formation of 14-nucleate (Text-Fig. 7) and 8-nucleate stage of the embryo-sac, the embryo-sac undergoes a considerable enlargement and bending (Text-Fig. 9).

A mature embryo-sac consists of an egg apparatus at the micropylar end, two polar nuclei in the middle, and three small antipodal cells at the chalazal end. The egg is large as compared to the size of the synergids and hangs down in the embryo-sac (Text-Fig. 9).

Fertilization.—Fertilization is porogamous. Syngamy and triple fusion occur more or less at the same time. One of the synergids is destroyed by the entry and rupture of the pollen tube. The other usually degenerates (Text-Fig. 10) or rarely persists for some time after fertilization (Text-Fig. 12). The polar nuclei remain free. The male gamete unites first with one of the polar nuclei and then all the three unite to form a primary endosperm nucleus (Text-Fig. 11). The pollen tube degenerates quickly. The antipodal cells rarely persist after fertilization (Text-Figs. 11 and 15).



TEXT-FIGS 17–23.

TEXT-FIGS. 17–23. *Haplanthus tentaculatus* Nees. Fig. 17. L.S. of ovule at stage shown in Fig. 18. Fig. 18. Embryo-sac showing 2-nucleate micropylar haustorium, central cellular endosperm, secondary haustorial cell and uninucleate chalazal haustorium. Fig. 19. Embryo-sac showing secondary haustorial cell in division. Fig. 20. L.S. of ovule at stage shown in Fig. 21. Fig. 21. Chalazal part of the embryo-sac showing cellular endosperm and secondary haustorial cells with hypertrophied nuclei and binucleate chalazal haustorium. Fig. 22. L.S. of ovule showing embryo-sac at globular stage of the proembryo (Diagrammatic). Fig. 23. Magnified view of portion 'A' from Fig. 22.

(*e*, embryo; *s*, suspensor; *mh*, micropylar haustorium; *ce*, central cellular endosperm; *se*, secondary haustorium of the celluar endosperm; *ch*, chalazal haustorium; *j*, jaculator; *f*, funiculus.)

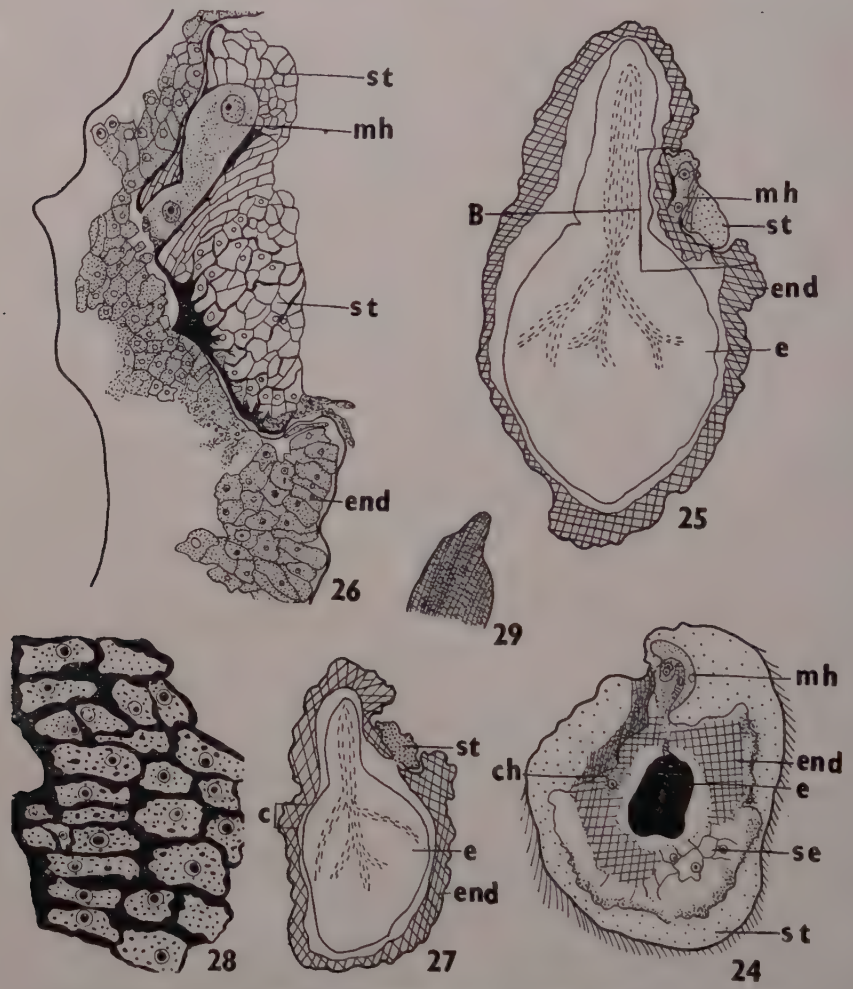
(Fig. 17, × 100. Figs. 18 and 19, × 420. Figs. 20 and 22, × 70. Fig. 21, × 250. Fig. 23, × 350.)

Endosperm development.—The primary endosperm nucleus divides earlier than the zygote (Text-Fig. 13) and a small chalazal chamber and a large upper chamber are formed (Text-Fig. 13). The upper chamber by further transverse partition gives rise to the central chamber and the micropylar chamber (Text-Fig. 15). The chalazal and the micropylar chambers develop into the chalazal and the micropylar haustoria respectively while the central chamber gives rise to the cellular endosperm. Thus the endosperm development up to the formation of three chambers is similar to that in the other members of the Acanthaceae (Mauritzon, 1934; Maheshwari and Negi, 1955; Phatak and Ambegaokar, 1956, 1957; Mohan Ram, 1956; Mohan Ram and Sehgal, 1958 and Johri and Hardev Singh, 1959).

Cellular endosperm and seed formation.—The very first division of the nucleus of the central chamber is followed by a wall (Text-Fig. 16), and two cells are formed as in *Crossandra* and *Acanthus* (Mauritzon, 1934), *Barleria prionitis* (Phatak and Ambegaokar, 1956), *Acanthus ilicifolus* (Phatak and Ambegaokar, 1957) and *Elytraria acaulis* (Johri and Hardev Singh, 1959). These two cells by further divisions produce the central cellular endosperm.

During the development of the cellular endosperm, one of its cells, in contact with the integument gets hypertrophied along with its nucleus and becomes vacuolated (Text-Fig. 18). It divides (Text-Fig. 19) and its derivatives along with the other cells of the cellular endosperm in the vicinity of the integument become hypertrophied, and absorb food from the surrounding integumentary cells (Text-Fig. 21).

The absorption of nutrients from the integument is vigorous and constant. When the absorption is maximum, *i.e.*, at the globular stage of the proembryo, the cell walls of these haustorial cells which come in contact with the integumentary cells begin to show weak undulations. Their folds enter the integumentary cells (Text-Fig. 23), break them down and incorporate their contents (Text-Figs. 23 and 24). These cells of the central endosperm mass, which are haustorial, perform the function of absorbing food from the surrounding



TEXT-FIGS. 24–29. *Haplanthus tentaculatus* Nees. Fig. 24. L.S. of ovule at the cotyledonary stage of the proembryo (Diagrammatic). Fig. 25. L.S. of ovule showing persistent endosperm, remnants of the integument and micropylar haustorium (Diagrammatic). Fig. 26. Magnified view of portion 'B' in Fig. 25. Fig. 27. L.S. of mature seed (Diagrammatic). Note the degenerated mass of the integument at the micropylar end. Fig. 28. Magnified view of the persistent endosperm marked as 'C' from Fig. 27. Fig. 29. Jaculator.

(*e*, embryo; *end*, endosperm; *se*, secondary haustorial cells of the cellular endosperm; *mh*, micropylar haustroium; *ch*, chalazal haustorium; *st*, seedcoat)

(Fig. 24, × 70. Figs. 25 and 29, × 40. Fig. 26, × 150. Fig. 27, × 25. Fig. 28, × 350.)

integument and its translocation to the deeply placed endosperm and the embryo and as such they can be called as '*Secondary haustoria*', developed from the cellular endosperm.

The consumption of the integumentary cells continues (Text-Fig. 24) and in a mature seed almost the entire integument except a small portion around the micropylar haustorium gets absorbed by the central cellular endosperm mass, namely, the secondary haustoria (Text-Fig. 25). Later on this small portion of the integument along with the micropylar haustorium degenerates (Text-Fig. 27).

The developing embryo absorbs the endosperm mass, leaving only three to four of its layers behind in the mature seed (Text-Fig. 27).

As the integumentary portion is completely consumed by the cellular endosperm mass, the persistent endosperm assumes its function of a seedcoat. Its walls get thickened due to cellulose and mucilage (Text-Fig. 28). When the dry seeds are soaked in water, this mucilage swells up and begins to show warty swellings.

Such type of persistent endosperm, functioning as seedcoat is, so far, recorded only in *Elytraria acaulis* (Johri and Hardev Singh, 1959) belonging to the Tribe Nelsonoideae (Acanthaceae).

In *Justicia simplex* (Mohan Ram and Sehgal, 1958), a few layer of endosperm persist in the mature seed along with the integumentary seedcoat. Thus the formation of secondary haustoria and the persistence of endosperm functioning as seedcoat in *Haplanthus tentaculatus*, to the best of our knowledge, have not been recorded previously in any of the Acanthoideae of Engler and Prantl (1897).

Chalazal haustorium.—The chalazal haustorium, developing from the chalazal chamber, is a binucleate richly protoplasmic structure (Text-Fig. 19). At the globular stage of the proembryo, it becomes highly functional, and its micropylar part bulges out in the cellular endosperm (Text-Fig. 21). It persists upto the differentiation of the cotyledons of the embryo and then degenerates.

Micropylar haustorium.—Micropylar haustorium developing from the micropylar chamber is a binucleate, richly protoplasmic but non-aggressive body (Text-Fig. 18).

From the very young proembryo stage, it becomes highly functional and its nuclei become hypertrophied and conspicuous (Text-Fig. 19). It absorbs the nutritive substances from the surrounding integumentary cells and empties them. These cells develop thickenings on the walls. The micropylar haustorium remains in healthy condition up to the very late stage, *i.e.*, up to the formation of the cotyledons and the differentiation of the radicle (Text-Fig. 25), and then collapses.

Jaculator.—A small protuberance arises on the funiculus nearly after the formation of cellular endosperm in the central chamber and functions as the jaculator. It is very small, blunt and is broadened at the base in mature seed.

Discussion

According to Mauritzon (1934), the subtribe Andrographideae shows affinity with the tribe Thunbergioideae in regard to its nature

of seed, position of micropylar haustorium and one-sided expansion of the endosperm above the embryo; and hence he suggested its transfer to the tribe Thunbergioideae. The present studies do not support this view.

The morphological and embryological features noted in *Haplanthus tentaculatus* such as its peculiar pollen grains, presence of a large number of seeds in the mature fruit, weak development of the jaculator, the formation of secondary haustoria from the cellular endosperm and the persistent endosperm in the mature seed functioning as seedcoat are not met with in any of the members of Acanthoideae-Imbricatae (Engler and Prantl, 1897) or in the Justicieae (Hooker, 1885) to which the subtribe Andrographideae is assigned.

Bremekamp (1948) is of opinion that "the Andrographideae are the only Acanthoideae with articulated shoots, with an epidermis provided with cystoliths in which a bilabiate corolla and ascending aestivation of the lobes is found in pluri-ovular ovary cells. Their pollen grains, moreover, show a structure which is not met with elsewhere. They form, therefore, a well-defined distinct group".

The embryological data presented here on *Haplanthus tentaculatus* favours Bremekamp's views.

The presence of a large number of seeds, weak development of jaculator, the absence of formation of free nuclei in the central chamber, persistence of endosperm and long persistence of micropylar haustorium suggest its close affinity with the genus *Elytraria* (Phatak and Ambegaokar, 1955 and Johri and Hardev Singh, 1959), a member of the tribe Nelsonoideae.

Apparently assignment of the subtribe Andrographideae to the tribe Nelsonoideae appears to be more satisfactory. Alternatively separation of the subtribe Andrographideae from the tribe Acanthoideae and its transfer to a separate tribe may be justifiable. However, a detailed study of the other genera of Andrographideae would be necessary to confirm the suggestion.

Summary

The bi-lipped flowers have two two-celled anthers. One of the anther-lobes is bearded at the back and the pollen grains belong to 'Daubenpollen' type of Engler and Prantl (1897).

The superior bicarpellary ovary has four ovules in each cell on axile placenta. The ovules are unitegmic, campylotropous and tenuinucellate.

The hypodermal archesporial cell functions directly as the megaspore mother cell. The development of embryo-sac corresponds to the 'Polygonum' type.

The synergids and the antipodals are ephemeral but rarely one of the synergids may persist and become hypertrophied.

Fertilization is porogamous. Syngamy and triple fusion occur more or less at the same time.

The endosperm is of 'Cellular' type. First division of the primary endosperm nucleus is followed by a wall to form a smaller chalazal and a larger upper chamber. The latter by another transverse partition gives rise to the micropylar chamber and the central chamber. The micropylar and the chalazal chamber develop into haustoria.

Cellular endosperm is formed from the central chamber. The free nuclear divisions are absent. Some of the cells of the cellular endosperm touching the integument enlarge in size, get vacuolated and act as secondary haustoria. They absorb food material from the surrounding integumentary cells. The consumption of the integument by the advancing endosperm is so vigorous that in a mature seed no integumentary cells are left to form the seed-coat. Ultimately only a few layers of persistent endosperm function as the seed-coat.

The chalazal haustorium is binucleate, richly protoplasmic and bulges in the cellular endosperm.

The micropylar haustorium is binucleate, non-aggressive and richly protoplasmic. It is highly functional up to the late stages in the embryo development and its nuclei get hypertrophied.

The jaculator is very small, blunt and is broadened at the base in the mature seed.

Acknowledgements

We express our sincere gratitude to Prof. T. S. Mahabale for valuable suggestions and for critically going through some slides and manuscript. We are also thankful to Prof. A. R. Chavan, Head, Department of Botany, for the facilities provided.

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————. 1957. Embryological studies in Acanthaceae—III. Endosperm and embryo development in *Acanthus ilicifolius*, Linn. *Ibid.* **6**: 1–10.

ROOT APICAL MERISTEMS IN MONOCOTS

II. Root Apex Organisation in Some Members of the Liliaceae *

By B. D. Deshpande

Department of Botany, Birla College, Pilani (Rajasthan)

(Received for publication on May 16, 1960)

Introduction

In the earlier paper the author (Deshpande, 1959) has interpreted the meristematic region in terms of the 'Quiescent Centre' concept of Clowes (1956). In the present paper the account of the root apical meristems and the root apex configuration in some members of the Liliaceae are described.

Materials and Methods

Most of the material was collected during the botanical excursions of the Birla College. Species of *Sansevieria*, namely, *S. thyrsiflora* and *S. hahnii* were made available to the author by Dr. Hecht of the State College of Washington. The author is grateful to him for the same.

The following species were taken for the investigation:

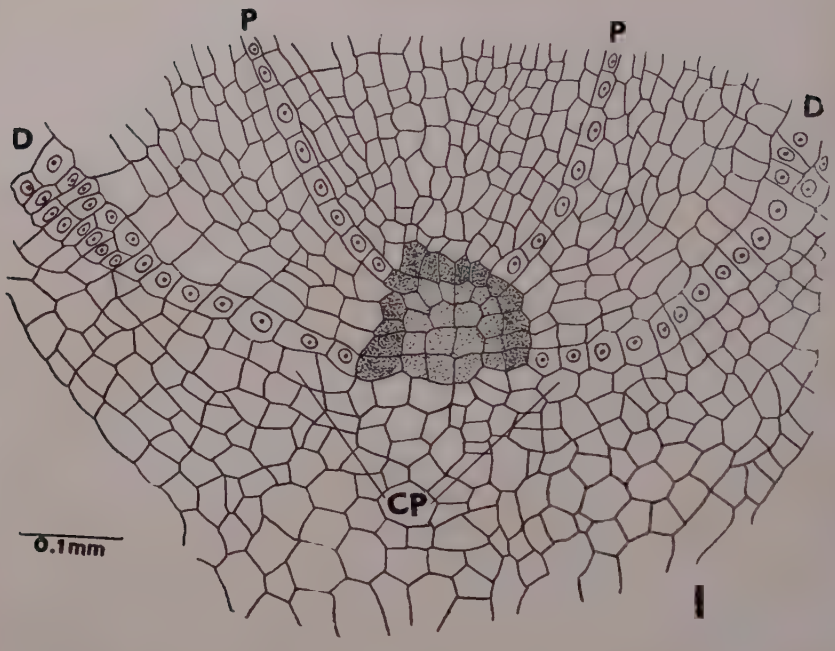
1. *Sansevieria thyrsiflora* Thun.
2. *Sansevieria hahnii.*
3. *Ruscus hypophyllum* Linn.
4. *Polygonatum oppositifolium* Royle.
5. *Hemerocallis flava* Linn.
6. *Aloe vera* Linn.

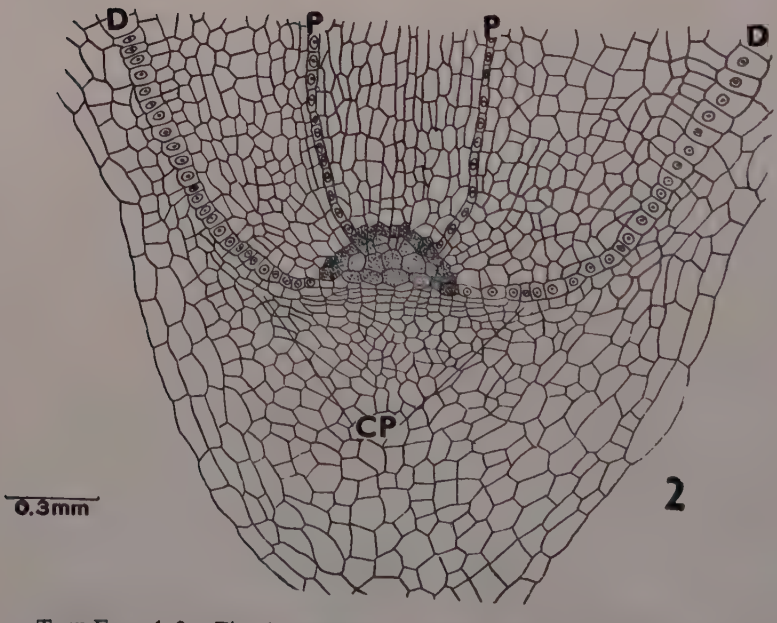
Observations

The root apex of *Sansevieria thyrsiflora* could be described in the following ways:

Three tiers of cells are seen at the apex (Text-Fig. 1). The lowermost tier, which rests on the first layer of the cap, has two centrally placed cells. The next tier has two tangentially flattened cell. The stelar pole consists of only two cells. The cap is independent and is contributed by a distinct layer, the calyptrogen.

* Based upon a part of the doctoral thesis approved by the University of Rajasthan.





TEXT-FIGS. 1–2. Fig. 1. Median l.s. of the root apex of *Sansevieria thyrsiflora*. *cp* = calyptrogen; D = dermatogen; P = pericycle. Fig. 2. Median l.s. of the root apex of *Ruscus hypophyllum*. *cp* = calyptrogen.

The above description is based upon the exact configuration of the apex.

These tiers of cells are surrounded by comparatively smaller cells on sides, except towards the cap region. These cells along with the tiers of cells at the apex give lighter red colouration when stained by methyl-green-pyronin combination. This zone which corresponds to the 'Quiescent Centre' is in its turn surrounded by a darkly-stained zone indicating the root initial region. From these darkly-stained cells further growth of the root body takes place by 'T' pattern.

Sansevieria hahnii has similar root apex as that of *S. thyrsiflora*.

Ruscus hypophyllum and *Polygonatum oppositifolium* resemble each other with regard to their root apex organisation. The median longitudinal section shows that at the apex there are two plates of superimposed cells keeping the construction of the apex. The first plate lying apposed to the calyptrogen has three cells. The second tier also has three cells (Text-Fig. 2). 'Quiescent Centre' is present and is surrounded by deeply stained cells.

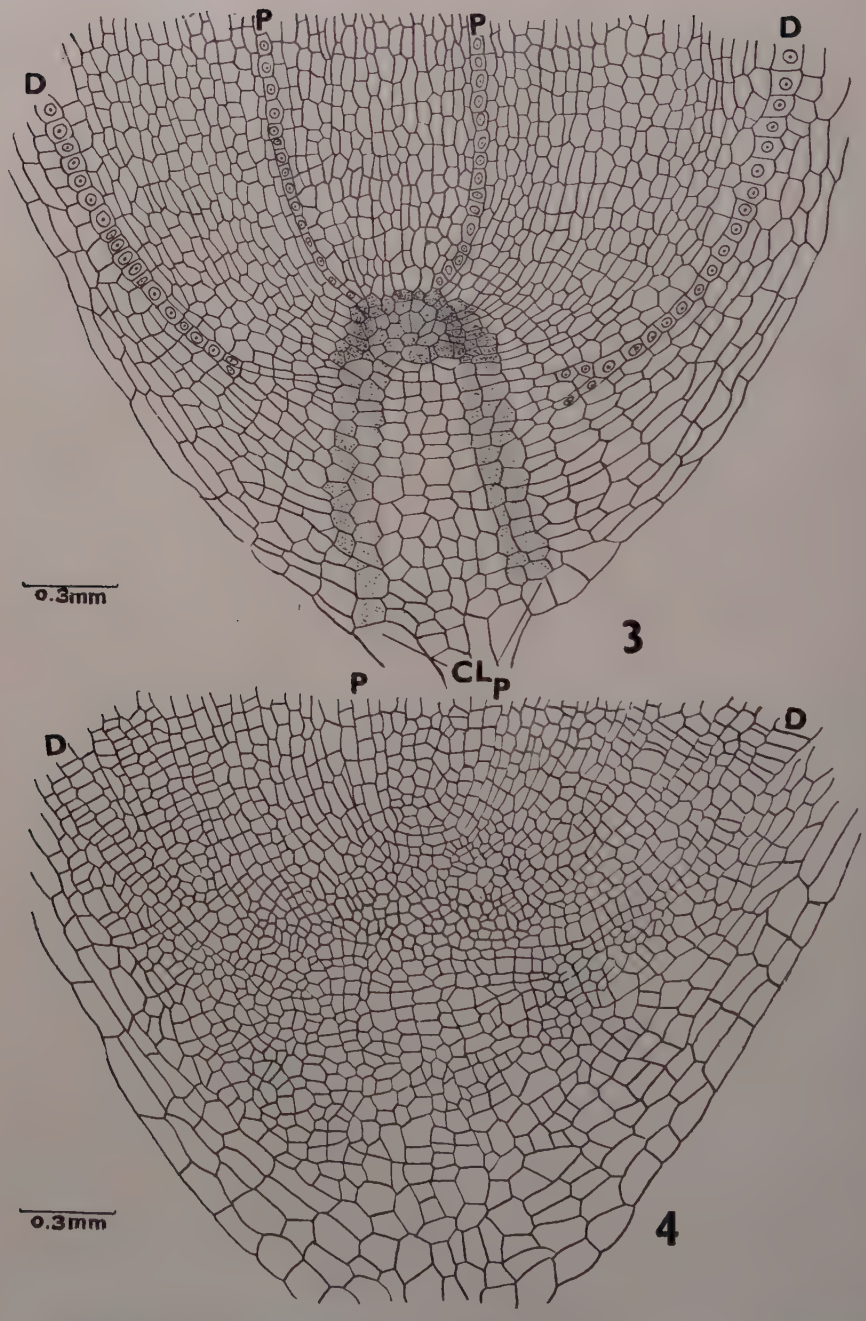
In *Hemerocallis flava* at the apex there is a shallow cup-shaped depression at the base of which occur the stelar pole. In front of the stelar pole occur the columella rows which maintain their width throughout the length of the cap. The sides of the cap are formed from the distinct uniseriate layer abutting on the protoderm (Text-Fig. 3). Protoderm when traced down to the apex appears to proliferate to form a little portion of the cap just near the columella. Columella seems to be independent of the rest of the cap.

The apical region of *Aloe vera* (Text-Fig. 4) does not exhibit any definite arrangement of the cells at the apex. There occurs a common group of cells which seem to be responsible for the formation of all the tissues in root. There is no distinct columella. The protoderm seems to proliferate to form a major portion of the cap.

Discussion

The apical structures of the members investigated fall under four types. The one where there occur three plates of superimposed cells to which belong *Sansevieria thyrsiflora* and *S. hahnii*; the second with two plates occurring in *Ruscus hypophyllum* and *Polygonatum oppositifolium*. The third type occurs in *Hemerocallis flava* where the stelar pole is distinct and rest of the tissues arise from the cells on the sides of the depression occurring at the apex. This appears to some extent similar to *Crinum latifolium* and *Agapanthus africanus* described in the earlier paper (Deshpande, 1960). The fourth type is found in *Aloe vera* where there is no distinction of cells at the apex in tiers. This type is considered to be of rather rare occurrence in monocots and it appears to conform to Popham's (1952) description of Janczewsk's type IV.

All these members show a 'Quiescent Centre' around which lie the root initials. The nature of the quiescent centre is essentially similar to the one described for Amaryllidaceae (Deshpande, 1960).



TEXT-FIGS. 3–4. Fig. 3. Median l.s. of *Hemerocallis flava*. *cl* = columella; D = dermatogen; P = pericycle. Fig. 4. Median l.s. of the root apex of *Aloe vera*.

From these root initials further growth in the root body takes place clearly by definite 'T' pattern. The analysis of the cell complexes in the root body and in the root-cap reveal contrasting mode of 'T' formations. In the root body the capital of the 'T' is pointed towards the apex. While in the sides of the cap the capital of the 'T' faces the root body side. This difference in the direction of the capital of 'T' brings about a contrast between the root body and the root-cap. This pattern involves the consideration of 'Korper Kappe' concept of Scheupp (1926). According to this concept the 'T' formations in the root body is of 'Korper' type and that in the cap is 'Kappe' type. Wagner (1939) made use of this theory for describing many root apices of angiosperms, so also Clowes (1950) for *Fagus*.

In the present paper somewhat fuller consideration is given to the relation between root-cap and the root body. Haberlandt (1914) mentions six types of apical structures based upon this aspect. Of these six types he has mentioned a few members of the Liliaceae showing the sixth type of organisation. According to Haberlandt's description of this type the meristems of the root-cap and root proper coalesce to form a common primordial meristem. The protoderm, however, behaves differently inasmuch as it takes no part in the formation of the root-cap, if it is present at all.

According to the author's observations there are mainly three types of root apices based upon the relation of the root-cap with the root body.

1. Where the cap is independent of the root body, but is indistinguishable into columella and the peripheral region. This is observed in *Zephyrantes tubispatha* of the Amaryllidaceae and *Sansevieria thyrsiflora*, *Ruscus hypophyllum* and *Polygonatum oppositifolium* of the Liliaceae.

2. Where the cap is distinguishable into columella and the peripheral region, both being independent of each other in histogenesis. In this two following subtypes are observed:

(*a*) Peripheral rows of the cap are independent of the root body, being formed by a uniseriate layer. The dermatogen has no role in the formation of the cap. This is observed in *Haemanthus coccineus* of the Amaryllidaceae (Deshpande, 1959).

(*b*) In addition to the distinct layer forming peripheral rows, a portion of the cap is formed by the proliferation of the dermatogen, as seen in *Agapanthus* and *Crinum* of Amaryllidaceae (Deshpande, 1960) and *Hemerocallis flava* of the Liliaceae.

3. Here the cap is related to the root body and protoderm also takes part in the formation of the cap by its proliferation. There is no distinct columella. This type is exemplified by *Aloe vera*.

The root-cap is supposed to be independent in monocotyledons, being formed by 'calyptrogen'. While this may be true in certain roots as in grasses, it is seen from the present study that dermatogen takes part in the formation of the cap. The view that the cap is the proliferation of dermatogen was put forward by Hanstein (1868). Eriksson* terms this condition 'dermo-calyptrogen' pointing out the relationship between dermatogen and the root-cap.

In the roots which show distinct columella the root-cap can be distinguished into two regions—first, the periphery of the cap, and the second, the columella of the cap. Distinct and broad columella has been observed in *Crinum*, *Agapanthus* and *Haemanthus* of Amaryllidaceae (Deshpande, 1960) and *Hemerocallis flava* of the Liliaceae. Here the columella rows appear to extend deep down and touch a few cells occurring in front of the stelar pole. Columella does not seem to have any histogenetic relationship with the sides of the cap. Their independence is further indicated by the fact that cytologically columella rows maintain the same width throughout as that of its initials, which occur just adjacent to and in front of the stelar pole. Kasapligil (1954) in his description of the zonation of the root apices of *Umbellularia californica* and *Laurus nobilis* recognises columella initials as forming an inverted cup just below the promeristem.

* Quoted by Haberlandt (1914).

Summary

The root apex organisation of the members of the Liliaceae investigated exhibit 'Quiescent Centre' similar to that of Amaryllidaceae. The root apices have been classified based upon the relationship between the root body and the root-cap. It has been pointed out that in some members their protoderm proliferates to form a part of the root-cap. Columella, wherever present, is independent of the rest of the cap.

Acknowledgements

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FUNGI CAUSING PLANT DISEASES AT JABALPUR (MADHYA PRADESH)—VII

By G. P. Agarwal and S. K. Hasija

Department of Botany, Mahakoshal Mahavidyalaya, Jabalpur

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This paper is intended to record more parasitic fungi from Jabalpur as a part of the study of the fungus flora of this region undertaken by the senior author and his students. The first six contributions (listed under reference) describe 127 fungi causing plant diseases. This seventh paper on the series deals with six deuteromycetes which include one new species, four new fungus records for the country and one new host record for *Myrothecium roridum*.

The number of the species are the serial numbers of the fungus flora of Jabalpur.

128. *Deightoniella jabalpurensis* Agarwal and Hasija sp. nov. on leaves of *Euphorbia geniculata* Orteg, Waterworks, September, 1959, Leg, Hasija.

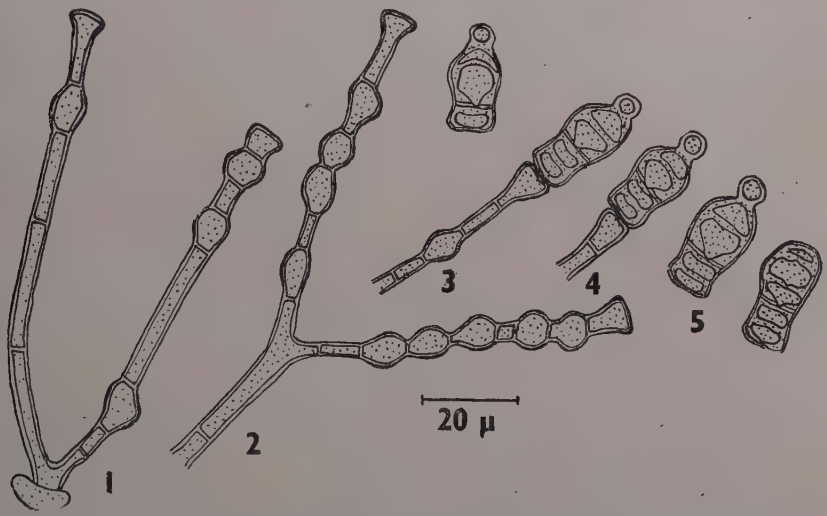
Symptoms of the disease.—The disease starts as brown pin-head spots from any part of the leaf. The spots become circular to irregular, with the central region pale-coloured bounded by a dark brown margin and up to 8 mm. in diameter. Spots often coalesce and increase the diseased surface. The chief veins are freely traversed.

The causal organism.—Conidiophores brown, erect, straight or curved, simple or branched, smooth, septate, arising singly or in twos, upper part torulose, composed of chains of globose to subglobose cells which measure 10·1–12·4 μ in diameter, conidiophores 27·9–155 μ long and at non-torulose part 3·9–6·2 μ wide; conidia produced singly at the tip of the conidiophore; conidiophore proliferates successively through the scars of the fallen conidium and produces sporogenous cells and conidia each time this process takes place; conidia concolorous with the conidiophores, campanulate, mostly 3-septate, seldom 2- or 4-septate, third cell from the base is the largest, epispore smooth, often a hyaline swelling arises at the tip of the apical cell of the conidium, this swelling becomes globose to subglobose, brown and measure 6·2–18·3 μ in diameter, scar at the basal end present indicating point of attachment to the conidiophore, conidia 24·1–40·3 $\times$ 9·3–15·5 μ, average 30·1 $\times$ 13·5 μ.

The fungus may best be placed in the genus *Deightoniella* on the basis of such features as the production of phragmospores singly on torulose conidiophores capable of successive proliferation and fruiting.

The present fungus differs from all other taxa classified in this genus so far (*see* Ellis, 1957; Subramanian, 1958) in its distinct characteristic conidia. The specimen was examined by Dr. Ellis who reports, "An interesting new species—nothing like it has been described on *Euphorbia*. The best described genus for this is *Deightoniella*".

It is, therefore, being described here as a new species, *Deightoniella jabalpurensis*. The only other species of the genus known from India is *D. indica* Subramanian (Subramanian, 1958).



TEXT-FIGS. 1–5. *Deightoniella jabalpurensis*. Figs. 1–2. Conidiophores,. Figs. 3-4. Conidiophores bearing conidia. Fig. 5. Conidia.

Deightoniella jabalpurensis AGARWAL AND HASIJA SP. NOV.

Conidiophori brunnei, erecti, recti vel curvati, simplices vel ramosi, leves, septati, singuli vel bini, torulosi in parte superiore, constantes e cellularumcatenis globosarum vel subglobosarum, quae dimetiuntur 10·1–12·4 μ; conidiophori 27·9–155 μ longi, et ad partem non-torulosum 3·9–6·2 μ lati. Conidia producta singulariter ad apicem conidiophororum, qui proliferi evadunt successive per cicatrices conidiorum deciduorum et producunt cellulas sprogenas et conidia in singulis proliferationibus. Conidia eiusdem coloris as conidiophori, campanulata, vulgo ter septata, raro bis vel quatter septata; cellula tertia a basi maxima est, episporo levi; saepe tumescentia hyalina producitur ad apicem cellulae apicalis conidiorum, quae tumescentia evadit globosa vel subglobosa, brunnea et magnit. 6·2–18·3 μ diam., cicatrice ad basim monstrante punctum unionis cum conidiophoro; conidia 24·1–40·3 × 9·3–15·5 μ, mediet. 30·1 × 13·5 μ.

In foliis *Euphorbiae geniculatae* Ort. ad Jabalpur in India, mense septembri anni 1959, leg. Hasija. Typus positus in Herbario Instituti Mycologici 'Commonwealth' in Kew, No. 79011.

129. *Alternaria gomphrenae* Togashi on leaves of *Gomphrena globosa* L., Wright Town, November, 1959, Leg. Hasija and Lele.

Symptoms of the disease.—The disease first appears as small violet pin-head spots on any part of the leaf. Spots become circular to irregular, with the central region yellow to ash-coloured bounded by a violet margin. Sometimes distinct zonations are formed in the central region, yellow alternating with grey. Midrib and the main veins are freely traversed.

The causal organism.—Conidiophores light brown, erect, straight or curved, smooth, septate, with geniculations, scars present, sometimes base bulbous, 31–81 × 3–6 μ; conidia brown, ellipsoid to obclavate, 2–11 septate, apex gradually elongated into a long beak which is subhyaline, septate or non-septate, epispore smooth, darker in colour, at times constricted at the septa, 34–127 × 9·3–14 μ. But of 140 spores examined only 16 showed longitudinal septa, 14 spores with one and 2 spores with two longitudinal septa.

So far *Alternaria gomphrenae* has not been reported from anywhere in India. It is a new fungus record for the country.

The species has been identified by Dr. M. B. Ellis and Dr. E. G. Simmons. The material is deposited in the Kew Herbarium No. 79001.

130. *Tripospórium myrti* (Lind.) Hughes on leaves of *Woodfordia fructicosa* (L.) Kurz, Waterworks, December, 1959, Leg. Hasija.

Symptoms of the disease.—The disease first appears as small dark brown spots only on the upper surface of the leaf. Spots become irregular and the central region turns light brown with a dark brown margin. Often the green of the leaf around the spots turns pale. Spots often coalesce. Midrib is not crossed. The whole tree gets badly infected.

The causal organism.—Conidiophores light to dark brown, septate, simple or branched, with distinct knee-bendings, tips may be hyaline, 90·8–127·1 × 3·9–4·7 μ, average 102·5 × 4·1 μ; conidia brown, with 2–4 radiating arms from a single cell, arms 2–5-septate, with tips hyaline, at times constricted at the septa, arms 10·9–49·6 × 4·7–6·9 μ, average 38·8 × 5.3 μ.

So far there is no record of *Tripospórium myrti* from India. It is a new fungus record for the country.

The species was identified by Mr. Sutton of the Commonwealth Mycological Institute, Kew, England.

131. *Pestalotiopsis carbonacea* Steyaert on leaves of *Hemidesmus indicus* Br., Waterworks, December, 1959, Leg. Hasija.

Symptoms of the disease.—The disease starts as small light brown spots from any part of the leaf. Generally there is only one spot per

leaf, seldom two but never more. Spots become circular to irregular with the central region light brown bounded by a violet margin and up to 15 mm. in diameter. On maturity acervuli appear as black dots in the central region.

The causal organism.—Acervuli broad, light brown, superficial, disc-shaped, 77·5–148·8 μ wide; conidia ellipsoid to fusoid, brown, usually 4-septate, end cells hyaline, central cells dark-coloured, epispore darker, 15·5–26·4 × 5·4–9·3 μ, average 22·5 × 7·3 μ, length of the coloured part 10·9–17 μ, average 15·4 μ.

Pestalotiopsis carbonacea is a new fungus record for the country and *Hemidesmus indicus* is a new host record for the fungus.

The species was identified by Mr. Sutton. The material is deposited in Kew Herbarium No. 79166.

132. *Myrothecium roridum* Tode ex Fr. on leaves of *Calotropis gigantea* R. Br., Mahakoshal Mahavidyalaya grounds, August, 1959, Leg. Hasija.

Symptoms of the disease.—The disease first appears as white dot-like spots with a brown halo only on the upper surface of the leaf. Spots enlarge and become circular to irregular. Zonations may or may not be present. On maturity the central region becomes ash-coloured and necrotic, in which develop acervuli as black dot-like structures. Later on the central necrotic tissue falls down forming holes. Spots seldom coalesce. Midrib forms a barrier.

The causal organism.—Acervuli broad, superficial, setae irregularly distributed in the acervulus, simple, dark brown, septate; conidiophores erect, branched, hyaline, septate, forming a palisade-like layer; conidia hyaline, mostly falcate, often cylindric, with rounded ends, single-celled, 18·6–27·1 × 2·3–3·8 μ, average 21·7 × 3 μ.

Myrothecium roridum has been reported on leaves of *Vigna unguiculata* from Bengal by Padmanabhan (1948) and on dead branches, leaves and bark of trees from Rohtak, East Panjab, by Ahmad (1949). *Calotropis gigantea* is a new host record for *M. roridum*.

The fungus was identified by Dr. Ellis. The material has been deposited in the Kew Herbarium No. 77916.

133. *Ascochyta oleandri* Sacc. on leaves of *Nerium oleander* L., Pariat Tank and Napier Town, September, 1959, Leg. Agarwal and Hasija.

Symptoms of the disease.—The disease starts as light brown spots from any part of the leaf. The spots develop in to irregular dark brown patches, with the central region light grey and involve more than half the leaf surface.

The causal organism.—Pycnidia dark brown, globose to subglobose, 46·5–108·5 μ in diameter, average 93·3 μ; conidia hyaline, ovoid, one septate, 4·9–9·7 × 3–3·9 μ, average 8·2 × 3·3 μ.

So far there is no record of *Ascochyta oleandri* from India. It is a new fungus record for the country.

The species was identified by Mr. Sutton. The specimen is deposited in Kew Herbarium No. 79002 *a*.

Summary

The present paper describes 6 parasitic deuteromycetes from Jabalpur. It includes *Deightoniella jabalpurensis* Agarwal and Hasija, a new species, on *Euphorbia geniculata* Ort., *Alternaria gomphrenae*, Togashi on *Gomphrena globosa* L., *Tripospórium myrti* (Lind.) Hughes on *Woodfordia fructicosa* (L.) Kurz., *Pestalotiopsis carbonacea* Steyaert on *Hemidesmus indicus* Br. and *Ascochyta oleandri* Sacc. on *Nerium oleander* L., four new fungus records for India and *Myrothecium roridum* Tode ex Fr. on *Calotropis gigantea* R. Br., a new host record.

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THE RELATION OF IRON SUPPLY TO THE GROWTH AND ASCORBIC ACID CONTENT OF BARLEY PLANTS GROWN IN SAND CULTURE

By C. P. Sharma

Department of Botany, Lucknow University, Lucknow

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Introduction

Barley plants, especially the younger growths, are reported to develop chlorosis under conditions of iron deficiency (Wallace, 1951). Jacobson (1951), while describing the suitability of ferric potassium ethylenediaminetetraacetate for the maintenance of iron supply in culture solutions has also reported a chlorosis of barley plants grown with less than 5 p.p.m. iron supply. No information is, however, available on the iron requirement of barley plants, particularly with respect to the critical levels of iron supply for normal growth and optimal yields.

The present investigation was undertaken to find out the effect of graded levels of iron supply on growth, ascorbic acid, tissue concentration of iron and certain other macro- and micro-nutrient elements, chlorophyll content and catalase activity of barley plants. This paper deals with the effect of iron supply on the growth and ascorbic acid content of barley plants. The relation of iron supply to the tissue concentration of iron, the chlorophyll content and the catalase activity will be discussed elsewhere.

Materials and Methods

Culture.—Bailey (*Hordeum vulgare* var. K 12) was grown in sand culture during November 1956 to March 1957. The culture technique used was an adaptation of the one in use at the University of Bristol Research Station at Long Ashton (Hewitt, 1952). The sand for the culture studies was obtained from Shankergarh near Allahabad. The sand purification procedure was essentially the same as in use for iron deficiency experiments at Long Ashton. Water for the preparation of nutrient solutions was distilled in copper stills. Analytical Reagent grade salts were used for the preparation of culture solutions. Since it was also desired to find out the effect of graded levels of iron supply on the uptake of certain other micro-nutrient elements (Cu, Mn and Mo) nutrients used for the supply of the macro-nutrient elements and iron were carefully purified. The macro-nutrient stock solutions were freed from iron by two-fold phosphate precipitation procedure, described by Hewitt (1952). Iron was supplied as ferric citrate. The

ferric citrate was prepared free from manganese, copper and zinc by Hewitt's adaptation of Piper's method (Hewitt, 1952).

The composition of the culture nutrient solution was as follows:

Macro-nutrients, as mg. eq./L.:

K^+ 4; Ca^{++} 8; Mg^{++} 4; PO_4^{---}; NO_3^- 12; Na^+ 1·33.

Micro-nutrients, as p.p.m. in solution:

Mn^{++} 0·55; Cu^{++} 0·065; Zn^{++} 0·065; BO_3^{---} 0·37; Mo^{--} 0·05; and Co^{++} and Ni^{++} 0·006.

Iron was supplied at the following ten concentrations:

0·056 (I), 0·14 (II), 0·28 (III), 0·42 (IV), 0·56 (V), 0·70 (VI), 1·40 (VII), 2·80 (VIII), 5·60 (IX) and 11·2 p.p.m. (X).

For the sake of convenience in the presentation of the results the levels of iron supply from 0·056 p.p.m. up to 0·56 p.p.m. are at times referred to as 'Lower levels' and those between 0·70 and 11·2 p.p.m. (both inclusive) as 'Higher levels'.

Culture plants were raised in 10″ clay pots with a central ground drainage hole. Pots were painted with three coats of bitumen. There were eight replicates for the lower levels and four for the higher levels of iron supply. The pots were arranged on wooden benches in two randomised blocks.

The application of the respective nutrient solutions was started after four days of sowing the seeds. Nutrient solutions were applied daily. At frequent intervals the containers were flushed with distilled water.

All plants were raised from seeds sown in sand. As many as twenty-five seeds were sown in each container. The plants were subsequently thinned leaving only two plants in each container at the higher levels and five plants at the lower levels. Thinning was so adjusted that the plants which would have been otherwise wasted were utilized for estimation of yields and analytical work. Three samples were thus drawn, first at 30–32, second at 60–62 and the third at 80–82 days growth.

Analytical.—The information presented in this paper deals with the estimation of yields and ascorbic acid at three stages of growth, namely, 30–32, 60–62 and 80–82 days.

Dry matter was determined by drying the plant material at 70° C. in a forced draught oven and yields are expressed as dry matter per plant.

Ascorbic acid determinations were made on finely chopped leaf material macerated in 5% metaphosphoric acid. The extracts were filtered and ascorbic acid concentration was estimated by rapid titration with 2, 6-dichlorophenol-indophenol (Harris and Ray, 1933).

Results

General growth and visual effects.—The characteristic effects of iron deficiency appeared at the lower levels of iron supply within 14 days of sowing of seeds, ten days of starting the treatments (Pl. XVI, Fig. 2). The leaf formed first (the first leaf) was apparently normal green at all the levels of iron supply but the subsequent leaves at an iron supply of 0·056 p.p.m. to 0·56 p.p.m. showed interveinal chlorotic stripping. At 0·056 to 0·28 p.p.m. iron supply the intervenal chlorosis eventually became more severe and of a general type. The chlorosis was most marked at 0·056 p.p.m. iron supply.

At 30–32 days of growth, leaves of most plants raised with 0·056 to 0·28 p.p.m. iron supply became severely chlorotic and totally bleached (Pl. XVI, Fig. 3). The latter eventually became scorched and withered. Generally the scorching and the withering of the leaves started from the leaf apices and spread progressively towards the base. The severity of the iron deficiency effects became more pronounced at the later stages of growth. In some plants raised at 0·056 and 0·14 p.p.m. iron supply the growing points were killed and the plants showed a partial collapse (Pl. XVI, Fig. 1). At 0·056 and 0·14 p.p.m. iron supply some plants developed brown lesions on the leaf lamina, some distance away from the base and this resulted in the collapse of the mesophyll (Pl. XVI, Fig. 3). Thei ron deficiency effects at 0·42 p.p.m. iron supply were milder than at 0·056 to 0·28 p.p.m. iron supply. Though most plants showed appreciable chlorosis scorching and withering was less severe and was generally restricted to the apical halves of the chlorotic leaves. At 0·56 p.p.m. iron supply the entire foliage was mildly chlorotic (Pl. XVI, Fig. 6) but at and beyond 0·70 p.p.m. iron supply, plants appeared to be normal (Pl. XVI, Fig. 5).

Table I

The effect of graded level of iron supply on the tillering of barley plant in sand culture

Stage of growth	Iron supply p.p.m. in solution									
	0·056	0·14	0·28	0·42	0·56	0·70	1·4	2·8	5·6	11·2
	No. of Tillers/plants. (Mean values for two blocks)									
30–32 days	2	2	2	2	2	3	3	3	3	3
60–62 days	2	2	2	2	3	16	16	14	15	16
80–82 days	2	2	2	3	4	19	19	20	20	20

Throughout the growth period the general growth of the plants raised at the lower levels (0·056 to 0·56 p.p.m.) of iron supply

remained severely restricted (Pl. XVI, Fig. 6). Tillering was suppressed (Table I) and leaves were small. At the higher levels (0·70 to 11·2 p.p.m.) of iron supply plants had many tillers and showed a luxuriant growth (Pl. XVI, Fig. 5). Plants raised at the lower levels of iron supply were rather spindly with the leaves at an acute angle as compared to the plants raised at the higher levels. At higher levels, plants were of a more spreading nature with leaves at larger angle. Inflorescence was not formed below 0·28 p.p.m. It was delayed at 0·28 and 0·42 p.p.m. and to a lesser extent at 0·56 p.p.m. iron supply. Between 0·28 and 0·56 p.p.m. iron supply ears were small and grains were poorly formed (Pl. XVI, Fig. 7). At and beyond 0·70 p.p.m. iron supply, inflorescence was well developed and grains appeared to be normal.

Yield.—At each stage of growth, plant yields were largely determined by the level of iron supply. The effect of iron supply on the yield was highly significant ($P = 0·01$).

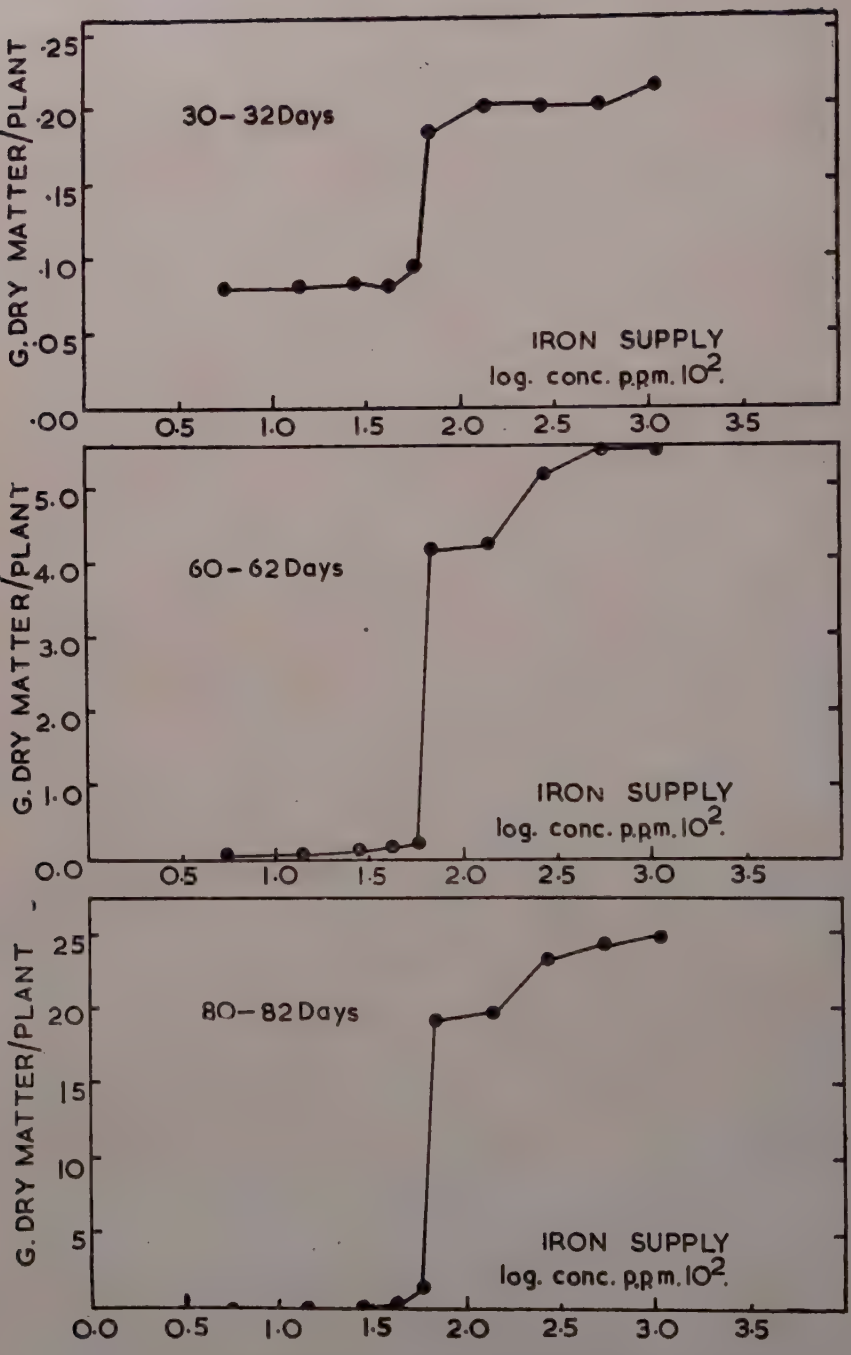
At 30–32 days growth, the differences in the yield of plants at the different iron levels were not marked but plants at the higher levels of iron supply showed significantly higher yields than at the lower levels. At 60–62 and 80–82 days growth, yield differences became appreciable. Increase in the iron supply, from 0·056 to 11·2 p.p.m., brought about an increase in the yield of plants. At each, 30–32, 60–62 and 80–82 days growth highest yields were found at 11·2 p.p.m. iron supply. The differences in the yield of plants between 0·056 and 0·56 p.p.m. and between 0·70 and 11·2 p.p.m. iron supply were generally not significant at any stage of growth. At all stages plant yields at the lower levels of iron supply remained very low.

It is evident from Text-Fig. 1 that the yield curves, yield expressed arithmetically and iron supply logarithmically, at the three stages of growth, were generally sigmoid, with sharp regions of inflection at 0·56 and 0·70 p.p.m. iron supply. The sigmoid nature of the yield curve was more pronounced at 60–62 and 80–82 days growth when yield at the higher levels became many times higher than at 30–32 days growth.

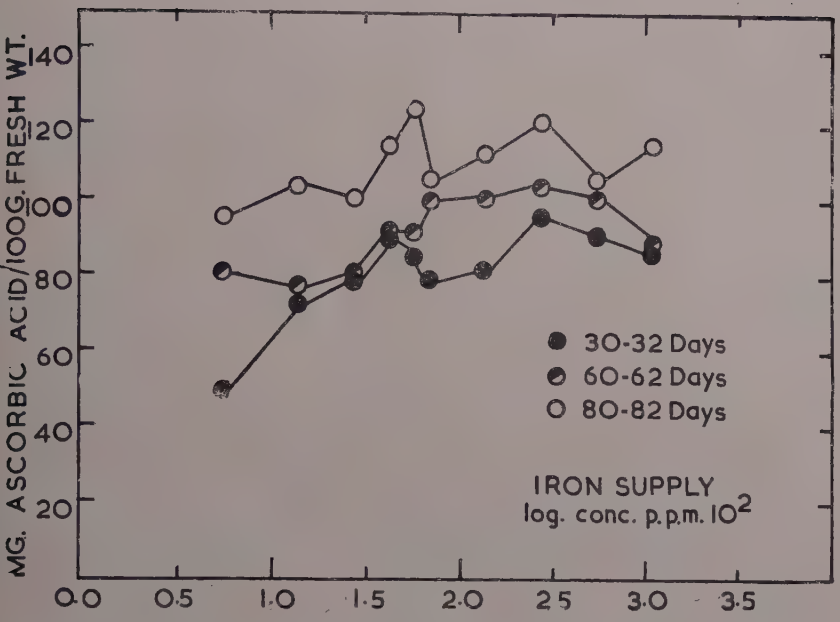
Ascorbic acid.—It is evident from an inspection of Text-Fig. 2 that the ascorbic acid content of plants was depressed at lower levels of iron supply. At each one of the three stages of growth, the ascorbic acid content of plants supplied with less than 0·42 p.p.m. iron supply was lower than in plants receiving 0·42 p.p.m. or a higher iron supply. The differences between the ascorbic acid content of plants supplied with varying levels of iron at the three stages of growth were generally not appreciable or significant but the overall effect of the iron supply on the ascorbic acid content of plants was significant ($P = 0·05$) at 30–32 and 60–62 days growth.

Summary and Conclusions

1. The relation of iron supply to the growth, visual effects and the ascrobic acid content in barley plants has been described.



TEXT-FIG. 1. The effect of iron supply on the yield of barley plants.



TEXT-FIG. 2. The effect of iron supply on the ascorbic acid content of barley plants.

2. Barley (*Hordeum vulgare* var. K 12) plants were grown in sand culture at ten levels of iron supply ranging from 0·056 to 11·2 p.p.m.

3. Characteristic visual effects of iron deficiency were produced in plants receiving less than 0·70 p.p.m. iron supply. The concentration of 0·70 p.p.m. iron supply was found to be critical with respect to the visual effects of iron deficiency. Early symptoms of iron deficiency were observed within fourteen days of sowing of seeds. Additional information on the variations and the manifestation of the visual symptoms of iron deficiency has been provided.

4. Iron supply has been shown to determine the yield of barley plants. An increase in the supply of iron from 0·056 to 11·2 p.p.m. brought about an increase in the yields. The increase in yields was marked most between 0·56 and 0·70 p.p.m. iron supply. The critical level of iron supply, or the threshold value for near-maximal growth in barley was found to be 0·70 p.p.m. The narrow range of iron supply between 0·56 and 0·70 p.p.m. was critical for both, general growth (visual effects) and plant yields. The optimal level of iron supply for yields was 11·2 p.p.m.

5. The ascrobic acid content of plants was found to be related to the iron supply. A supply of iron lower than 0·42 p.p.m. brought about an appreciable decrease in the ascorbic acid concentration.

6. No definite relationship was found between the yield and ascorbic acid content of plants.

Acknowledgement

The author is grateful to Dr. S. C. Agarwala under whose guidance this work was carried out.

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Explanation of Plate XVI

Fig. 1. Photograph at 80 days growth, shows chlorosis of the foliage, death of the growing points and collapse of some plants at 0·056 p.p.m. iron supply.

Fig. 2. The characteristic symptoms at 0·056 p.p.m. iron supply at 14 days growth. First leaf normal green, subsequent leaves show severe intervenal chlorotic stripping or bleaching. The chlorotic leaves show scorching and withering of the apical part.

Fig. 3. Leaf of plants raised at 0·056 p.p.m. iron supply, showing necrotic lesion at the margin, some distance away from the base.

Fig. 4. Severe chlorosis and restricted growth at 0·056, 0·14, and 0·28 p.p.m. iron supply at 25 days growith. From left to right are arranged pots receiving 0·056, 0·14 and 0·28 p.p.m. iron supply.

Fig. 5. Comparative growth and visual effects at 60 days growth. Plants at the lower levels of iron supply show severe chlorosis and restricted growth. At higher levels plants are normal green and show luxuriant growth. From left to right are arranged pots receiving 0·056, 0·14, 0·28, 0·42, 0·56, 0·70, 1·4, 2·8, 5·6 and 11·2 p.p.m. iron supply.

Fig. 6. Photograph at 80 days growth, shows comparative growth effects and severity of chlorosis at 0·056, 0·14, 0·28, 0·42 and 0·56 p.p.m. iron supply.

Fig 7. Photograph at 110 days growth, shows the poorly formed inflorescene at 0·28 and 0·42 p.p.m. iron supply. No inflorescences were formed at 0·056 and 0·14 p.p.m iron supply. From left to right are arranged pots receiving 0·056, 0·14, 0·28 and 0·42 p.p.m. iron supply.

FIGS. 1-7

C. P. Sharma

STUDIES ON THE MINERAL NUTRITION OF *OOCYSTIS MARSSONII* LEMM.

I. Evaluation of Inorganic Macro-nutrient Concentrations for an Optimum Growth

By K. V. N. Rao

Hydrobiological Laboratories, Department of Botany, Osmania University, Hyderabad-Dn. 7

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Introduction

Aspects of mineral nutrition of algae have been first stressed by Artari (1904). Since then, inorganic nutrition of several algae has drawn the attention of many workers who mainly aimed at achieving a chemically defined medium that supports maximum growth of algae (Urhan, 1932; Pirson, 1940; Chu, 1942–43; Rodhe, 1948; Osterlind, 1949; Gerloff *et al.*, 1950 *a*, *b* and 1952; Provasoli *et al.*, 1954, Miller and Fogg, 1957; and Natarajan, 1960).

Majority of the investigators have employed the replacement technique. This method involves the maintenance of all ions in a nutrient medium constant, except the one under investigation, supplied in series ranging from zero to a level far above the expected optimum.

The present investigations have been made to evaluate a basic inorganic medium that offers optimum growth conditions for the green alga *Oocystis Marssonii* Lemm., which is being used for studies on nitrogen metabolism, in our laboratory. The culture of *Oocystis Marssonii*, strain 257/1 is obtained from Culture Collection of Algae and Protozoa, Botany School, Cambridge, England.

Material and Methods

Choice of the basic medium.—Out of the several media, Modified Bristol Solution (Bold, 1949) has been selected as the basic medium, mainly because of better growth of the alga observed on agar slants containing this medium than that of Knop, Benecke and Chu. Besides, this medium has a well-balanced phosphate buffer and a pH of about 7. This basic medium contains 0·250 g. of $NaNO_3$, 0·025 g. of $CaCl_2$ (anhydrous), 0·075 g. of $MgSO_4 \cdot 7H_2O$, 0·075 g. of K_2HPO_4, 0·175 g. of KH_2PO_4 and 0·025 g. of NaCl, 2ml. of A_4 solution (Arnon, 1938), 1 ml. of Fe-EDTA solution containing 5 mg. of Fe (Arnon *et al.*, 1955) and 3 mg. of Mo as MoO_3 per litre.

Culture apparatus.—The apparatus for culturing the alga for the present experiments consists of a raised wooden platform heavily coated with white enamel paint and carrying eight 4-feet long, 40 Watt, daylight fluorescent tubes. About six inches above from the source of light, is a tray with a perspex base fixed with parallel wooden racks and hung from an iron frame. The grooves on the wooden rack take in culture tubes.

The perspex tray is attached to a motor and is shaken with a horizontal movement of 5 inches, at a rate of 72 times per minute.

Calibration of culture tubes.—Even though rimless Pyrex brand test-tubes selected are of standard wall thickness, there are considerable differences in their internal diameters, and this alters the readings of optical density.

As it is very difficult to have enough number of test-tubes of the same internal diameter for all the experiments, groups of test-tubes with internal diameter ranging between 18·7 and 18·5 mm. are chosen, and the culture tubes of the same internal diameter are used for study of all the concentrations of any one of the deficient elements.

The internal diameter of each test-tube is determined by deducting the wall thickness from the external diameter for, it cannot be found out directly with the same accuracy as that of the external diameter, by means of slide calipers.

The test-tubes of each batch of identical internal diameters are numbered. Their suitability for the measurements of optical density has been verified by determining optical density of a known concentration of alga suspended in water. The culture tubes showing differences of optical density more than 5% are discarded. Two vertical lines 5 mm. long and diametrically opposite to each other are scratched on each test-tube with the help of a diamond pencil. The culture tubes are always kept in the same position with the vertical lines coinciding with a line marked on the holder, so that the optical densities are always measured with the same length of the beam and in the same plane.

Growth conditions.—The experiments are conducted at 20° ± 1° C. inside a thermostatically controlled low temperature room. All the cultures are continuously illuminated, the intensity being 3,000 lux.

pH of the media is determined by means of Leeds Northrup pH meter.

Growth determinations.—Optical density or photometric estimation of the light absorption by the cultures is taken as the index of growth in spite of its limitations as a quantitative method. This method is preferred because any number of periodical determinations can be done without exposing the cultures to contamination.

To suit the present conditions, Klett-Summerson Photoelectric colorimeter is modified as described below, resembling the photometers used by Chu (1942) and Åberg and Rodhe (1942).

A 20 mm. glass cuvette half-filled with water is used as a water trough. To this is fixed, in the centre, an adapter to hold the culture tube between the two opposing marks in a constant position by means of screws. A black plastic screen with a hole for the insertion of test-tube, placed above the adapter, acts as a light screen. Test-tubes with vertical lines marked at a suitable height coinciding with the lines drawn on the plastic screen are always kept with the particular diameters in position during successive readings.

The colorimeter has a logarithmic scale reading corresponding directly to optical densities or extinction values.

Every experiment is conducted in triplicate and reading of optical density is the mean of three separate determinations. Since the culture tubes are calibrated earlier, the differences in optical density were not more than 0·004.

Experiments

Preparation of inoculum.—Ten days old alga grown on agar slants is transferred to Modified Bristol Solution and grown for two days. The alga is then harvested, washed twice with sterile glass-distilled water. This inoculum is then distributed equally amongst specially designed 500 ml. conical flasks containing the media, otherwise complete, except for the absence of the particular element, with an object of obtaining a threshold deficiency of each of the elements under study. These cultures are aerated with a mixture of 0·5% CO_2 and air at a rate of 20 litres/hour and continuously illuminated for three days.

The inoculum thus grown under deficiency of a particular cation or anion is distributed to the sterile culture tubes which have serial concentrations of the element dissolved in 1 ml. of distilled water. The final volume of the medium with inoculum is adjusted as 10 ml. in all the test-tubes. All these transfers are carried under aseptic conditions.

For evaluating the optimum concentrations of the various cations and anions in a nutrient medium, the particular one bearing the anion or cation under study is omitted and the concentration of the accompanying cation or anion is made good of by employing another salt having an equivalent weight.

Solutions of phosphates, calcium chloride and the rest of the salts in the medium are autoclaved separately and on cooling mixed up under sterile conditions.

The culture tubes are kept in a slanting position over the rack of the culture apparatus and illuminated continuously at an intensity of 3,000 lux, at 20°–21° C. temperature.

The cultures are maintained till 21st day. Photometric estimations of growth are made periodically after inoculation, on 0, 1, 3, 5, 8, 11, 14, 18 and 21 days.

The optical densities attained on 21st day alone are shown in Table I.

TABLE I

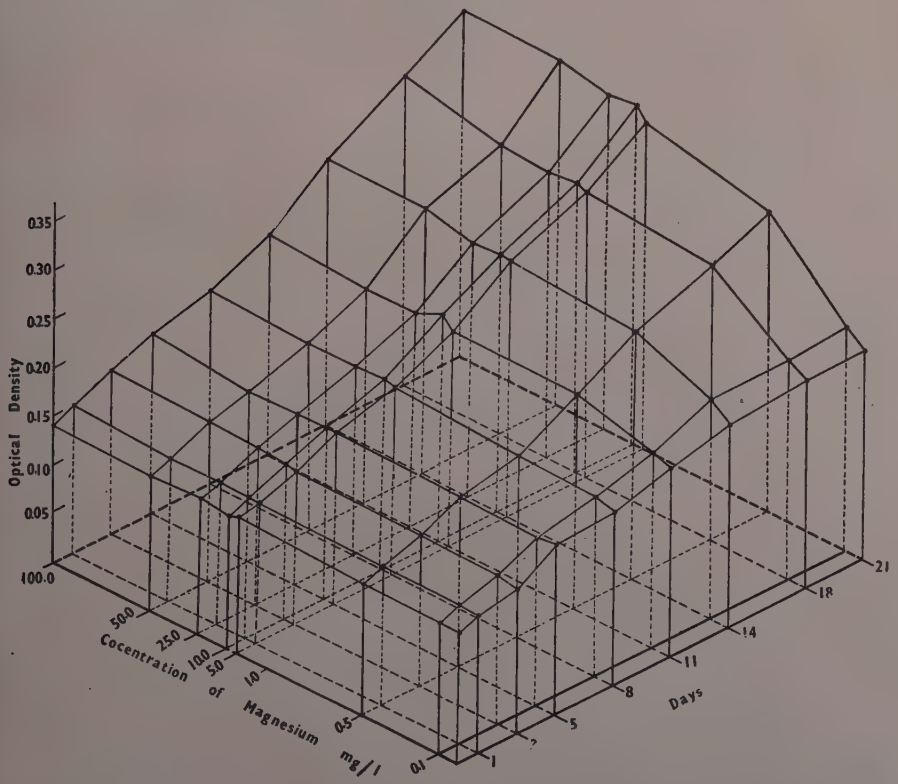
Concentration of deficient element mg./l.	Optical density								
	Na	K	Mg	Ca	Cl	P	S	NH_4–N	NO_3–N
0·0	0·424	0·568	0·216	0·440	0·452	0·504	0·456	0·080	0·080
0·01	0·440	0·578	0·216	0·460	0·460	0·508	0·460	0·080	0·080
0·1	0·480	0·580	0·230	0·464	0·460	0·556	0·472	0·086	0·090
0·5	0·480	0·595	0·310	0·464	0·460	0·568	0·492	0·092	0·090
1·0	0·480	0·620	0·320	0·476	0·468	0·600	0·492	0·096	0·106
5·0	0·480	0·624	0·338	0·512	0·468	0·644	0·500	0·156	0·168
10·0	0·480	0·628	0·350	0·516	0·472	0·679	0·516	0·184	0·192
25·0	0·496	0·628	0·352	0·516	0·478	0·690	0·548	0·186	0·220
50·0	0·512	0·640	0·356	0·480	0·484	0·698	0·548	0·286	0·260
100·0	0·516	0·660	0·356	..	0·476	0·700	0·540	0·300	0·340
150·0	0·516	0·662	0·356	..	0·476	0·700	0·540	0·280	0·300
200·0	0·510	0·650	0·350	..	0·470	0·700	0·480	0·260	0·286

Results

It can be seen from Table I that except for nitrogen (nitrate as well as ammonium) and magnesium, growth, as determined by optical density, did not completely cease at zero level, even though increased concentrations of ions within certain limits effected the growth progressively.

In case of sodium and potassium, the optimum range of concentrations for the best growth of the alga lie between 50–150 mg./l. and 100–150 mg./l. respectively. Slight inhibition is caused at the level of 200 mg./l.

In the magnesium series, relatively poor growth is observed at the lower concentrations up to 0·1 mg./l. and the cells have become pale green in colour. Besides, these cells are larger with thick cell-walls and form aggregates. Similar observations have been made by Finkle and Appleman (1953). The optimum range of concentrations for supporting the best growth is between 25 and 150 mg./l. Little inhibition is found at 200 mg./l. The growth characteristics of the alga in this series on different days has been shown in Text-Fig. 1.

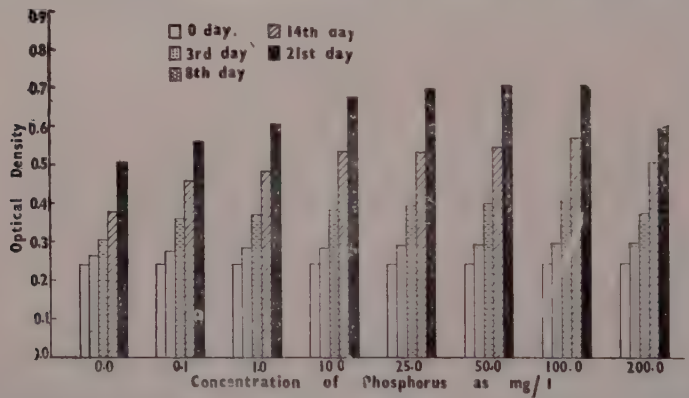


Text-Fig. 1. Isometric drawing of three dimensional model showing the relationship between the various concentrations of magnesium and growth on different days. (The scale denoting concentrations is broken at 1·0 mg. and 5·0 mg.).

With regard to calcium, growth was found to be best between 5 and 25 mg./l. even though with lower concentrations the growth was by no means poor. Inhibition of growth is found at a level of 50 mg./l. Because higher concentrations cause phosphate precipitation which not only interferes with the optical density but also adsorbs other ions, they were not employed.

Amongst the other elements forming anions, varying the concentrations of chlorine effected the growth slightly, the optimum concentrations being within the range of 25–50 mg./l. Generally speaking, the growth in this case seems to be almost independent of the concentration of the ions.

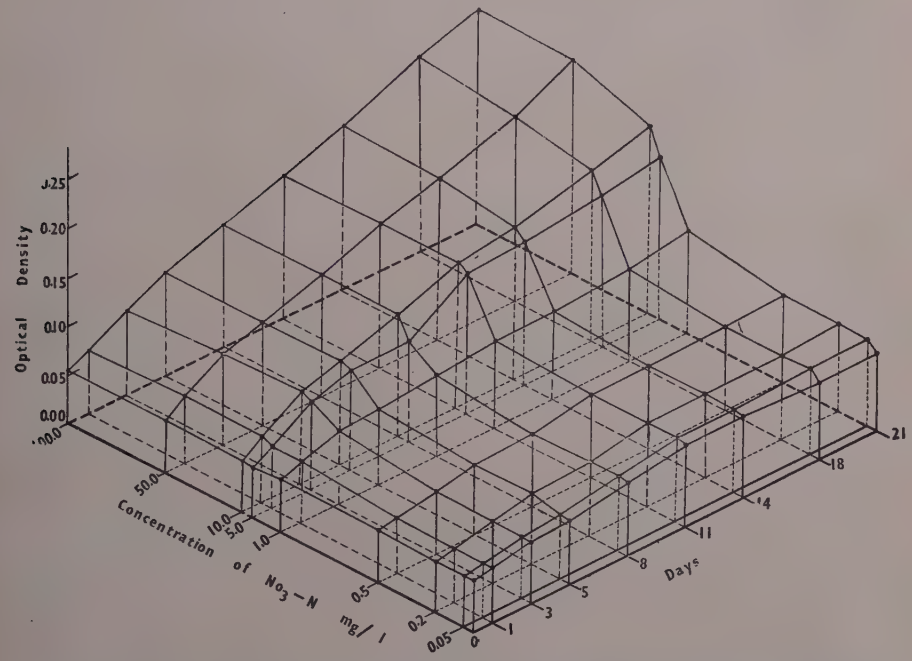
The optimum concentrations for phosphorus and sulphur seem to be within the range of 50–150 mg./l. and 25–100 mg./l. respectively. In both cases, the growth is slightly effected at the zero concentrations and slight inhibition has been found at highest concentrations. The growth pattern in phosphorus series is shown in Text-Fig. 2.



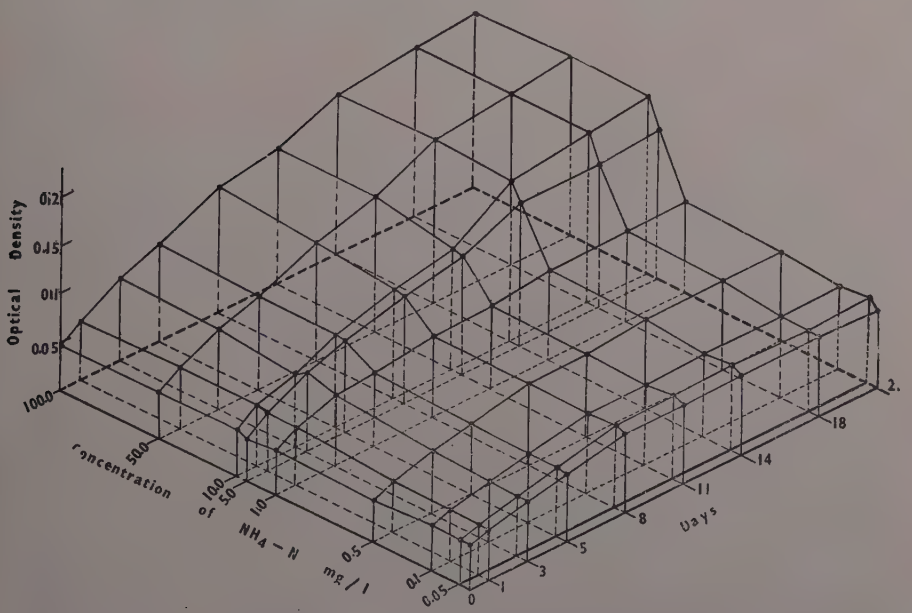
TEXT-FIG. 2. Histogram showing the effect of various concentrations of phosphorus as mg./l. on the growth of the alga on different days.

In case of nitrogen, the growth is almost arrested at the zero level, both in the ammonium and nitrate sources. There is a gradual increase in growth after the critical concentration of 5 mg./l. There is slight inhibition at the higher levels of 150–200 mg./l. The microscopic examination of cells revealed a pale yellow colour at lower concentrations which progressively becomes green in the upgrading series. The nature of growth, effected by the age and by various concentrations of nitrate-nitrogen, and ammonium-nitrogen, is represented in Text-Figs. 3 and 4 respectively.

The initial and final pH of culture media, in all other series than nitrogen, varied between 6·8 and 7·2. In case of nitrate-nitrogen series it varied between 6·8 and 7·6 and in case of ammonium-nitrogen series, it varies between 5·6 and 6·8.



TEXT-FIG. 3. Isometric drawing of three-dimensional model showing the relationship between the various concentrations of NO_3–N and growth on different days. (The scale denoting the concentrations is broken at 1·0 mg. and 5·0 mg.).



TEXT-FIG. 4. Isometric drawing of three-dimensional model showing the relationship between the various concentrations of NH_4–N and growth on different days. (The scale denoting the concentrations is broken at 1·0 mg. and 5·0 mg.)

On the basis of the above optimal concentrations, inorganic medium has been synthesised with the following constituent salts in the following proportions:

Salts	Mg./l.
$NaNO_3$	369·7
$CaCl_2$ (anhydrous) ..	26·31
$MgSO_4 \cdot 7H_2O$	253·3
K_2HPO_4	75·0
KH_2PO_4	175·0
KCl	50·47

The medium contains the following elements expressed as mg./l: Na 100; K 100; Mg 25; Ca 10; N 60·91; P 53·23; S 32·94 and Cl 40·32.

The growth of the alga in this medium has been compared with that of the original basic solution, the alga having been cultured in both the cases, in tubes containing 10 ml. of medium and as well as in 500 ml. conical flasks containing 150 ml. of medium for 21 days. The growth in the case of the culture tubes and flasks has been $125 \pm 15{\cdot}22$ and $137 \pm 21{\cdot}37\%$ as that of the Modified Bristol Solution, respectively.

Discussion

Data on the major elements of algae are difficult of comparison, firstly because of the different growth conditions under which the experiments have been carried out by various workers and secondly, because of the aim of the experiments not being the same. The latter assumes greater importance in case of a medium just sufficient to sustain adequate growth for shorter durations, will generally be found quite inadequate if the alga were to be grown for longer durations or the algal inoculum is denser and grown in larger vessels.

However, earlier workers have stressed some of the parameters of general application. Comparing low concentrations of phosphorus requirements, Gerloff *et al.* (1952), Miller and Fogg (1957), and Natarajan (1960) have observed that there is particular nitrogen/phosphorus ratio for the attainment of maximal growth of algae under their investigation. This N/P ratio varies from 15/1 for *Kirchneriella subsolitaria* West. (*cf.* Natarajan, *loc. cit.*) to 75/1 for *Microcystis aeruginosa* Kutz. (Gerloff *et al.*, *loc. cit.*). Rodhe (1948), however, does not specify any such N/P ratio but observes that *Scenedesmus quadricauda* (Turpin)

Brebisson required 1 mg. of phosphorus per litre, and 5 mg. of nitrogen per litre for maximal growth, even though it is quite marked for a few days, at lower concentrations.

The N/P ratio of the present alga is slightly less than unity, maximum growth at the lower concentrations of phosphorus equivalent to 12/1 N/P ratio being 8% less. Higher concentrations of phosphorus have been chosen in view of the buffering action.

Another factor that determines the growth is the optimal monovalent: divalent cation ratio. The ratio for the optimum growth of *Oocystis Marssonii* Lemm. is 5·71 : 1, and resembles *Monodus subterraneus* Petersen (Miller and Fogg, *loc. cit.*) and *Chlorella* Beijerinck, and may be grouped under those designated by Pearsall (1922) as requiring a high monovalent: divalent cation ratio.

The low requirement of calcium for the present alga is in conformity with the observations of earlier workers for *Ankistrodesmus falcatus* (Corda) Ralfs. (Rodhe, *loc. cit.*) *Scenedesmus quadricauda* (Turpin) Brebisson (Osterlind, *loc. cit*), *Selenastrum westii* G. M. Smith (Natarajan, *loc. cit.*) and *Chlorella* (Stegmann, 1940). Growth of the present alga is inhibited at higher concentrations of calcium, *i.e.*, 50 mg./l. This may be due to the interference of magnesium uptake, as has been found by Miller and Fogg (*loc. cit.*) who have observed the deficiency symptoms of magnesium in case of *Monodus subterraneus* Petersen. They also find that addition of chelating agent preferentially binds calcium, thereby increasing the availability of magnesium. The presence of chelating agent all through in the present serial concentrations of calcium and magnesium masks the antagonism or interchangeability of calcium-magnesium ions. Vollenweider (1950), working on *Oscillatoria rubescens* DC ex Gomont and *Ankistrodesmus falcatus*, observes that addition of calcium to media with sub-optimal levels of magnesium enhances the growth. The complexity and varied nature of the cation relations have been recently reviewed by Provasoli (1958).

Several workers have stressed the importance of Ca: Mg ratio as determining the optimal growth of the algae. But in majority of the cases the organisms possess a wide flexibility. The present alga has a Ca: Mg ratio of 1 : 2·5 at concentrations evaluated for optimum growth but the growth is slightly less even when the ratio is altered to 1 : 6 (*refer* Table I). This suggests the wide range of Ca: Mg for optimum growth.

The present alga resembles other chlorococcalean members in its requirements of potassium, magnesium and sulphate ions. Adequate growth was observed even at lower concentrations of the elements than specified in the table, but non-toxic higher concentrations have been chosen in view of their use for denser inoculum in larger volumes of media.

The growth of the alga seems to be independent of the concentrations of sodium and chloride ions within the ranges employed and

under the growth conditions mentioned herein. Similar observations have been made by Osterlind (*loc. cit.*) for *Scenedesmus quadricauda* (Turpin) Brebisson and by Rodhe (*loc. cit.*) for *Ankistrodesmus falcatus* (Corda) Ralfs. However, Allen and Arnon (1955) have demonstrated the essentiality of sodium for the growth of *Anabaena cylindrica* Lemm. and state that 5 p.p.m. of sodium is necessary for optimum growth. But, Eyster (1958) could prove the essentiality of sodium and chloride ions for *Chlorella pyrenoidosa* only when it is grown autotrophically, thereby indicating the probable involvement of the ions in photosynthesis.

Summary

The mineral nutrition of *Oocystis Marssonii* Lemm. has been studied with a view to evaluate an inorganic nutrient medium for optimum growth. The chemically defined nutrient medium contains the following elements expressed as mg./l.: Na 100; K 100; Mg 25; Ca 10; N 60·91; P 53·23; S 32·94 and Cl 40·32.

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RED ROT OF SUGARCANE—CRITERIA FOR GRADING RESISTANCE

By K. V. Srinivasan and N. R. Bhat

Sugarcane Breeding Institute, Coimbatore

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Red rot of sugarcane in India incited by *Glomerella tucumanensis* (Speg.) Arx *et* Mueller is a disease of standing canes resulting from either the primary infection of seed setts or secondary infection of canes caused by conidia through nodal penetration. Regardless of the mode of infection, it is reasonable to assume that the susceptibility of any cane variety will be determined, firstly, by the rate and amount of tissue invasion by the fungus and, secondly, by the amount of damage the variety suffers on that account, though, wherever the disease is caused principally by secondary infection, tissue susceptibility may occasionally be masked by resistance to nodal penetration, *e.g.*, in variety Co. 312 (Chona, 1950). As marked differences are observed in lesion lengths produced in different varieties by standard artificial inoculation of the standing canes with cultures of the pathogen, Indian sugarcane pathologists have advocated the use of the lesion length as criterion in judging susceptibility of varieties (Chona, 1954; Anonymous, 1959). According to this method, the disease is estimated in terms of the average lesion length produced inside the canes artificially inoculated by what is known as the 'plug method' which is an adaptation of a technique used by Grainger and Horne (1924). The standard for comparison is either Co. 213 or any other variety which may happen to develop the maximum average lesion length during the season. A variety with an average lesion length of less than 25 per cent. of the standard is considered resistant, one having between 25 and 50 per cent. moderately resistant, and one between 50 and 100 per cent. susceptible (Chona, 1954).

The average lesion length as an index of resistance has, indeed, served a useful purpose for several years in the absence of any better criteria, its chief merits being its simplicity and convenience as a yardstick of susceptibility in routine examination. Unfortunately, far too much precision and sanctity have been attributed to it and its very glaring shortcomings ignored. Due consideration has not been given to the appreciable variations occurring in the lesion length in even the self-same variety and to the characters of the lesion. As a result, one is often left in considerable doubt as to the intrinsic rate and amount of tissue invasion that any pathogenic strain can cause in any particular variety, and the reaction at times departs substantially from the one predicted on the basis of previous tests. From data gathered by the

first author in testing large numbers of varieties over the years, it is felt that certain other characters of the disease syndrome rather than the 'average lesion length' deserve to be given due recognition in order to get a more dependable picture of pathogenic behaviour in host varieties. Not less important is it to assess the overall damage that a variety suffers from a particular amount of invasion of its tissue by the pathogen. The relative importance of all these factors in comparison with the sole criterion of average lesion length is discussed below with a view to evolving a workable scheme for evaluating varietal resistance. Resistance offered by the canes to penetration from outside and the consequent infection by the fungus, in the tissues at the nodes, is not considered in this context, and only the resistance offered by canes into which a culture of the fungus has been introduced by the plug method, is considered.

1. Drying of Tops

The extent of overall damage suffered by an affected crop is best indicated by the symptoms of yellowing and drying of the tops. This may be accompanied by hollowing of canes and shrinking of the rind to a greater or lesser extent. As is to be expected, it has been observed that varieties differ markedly in the rapidity with which their tops dry up for comparable development of red rot lesions in their canes. Practical considerations warrant that this character (*i.e.*, drying of tops) must be considered to represent the highest degree of susceptibility. Characters of the lesion are required only for distinguishing the grades of tissue invasion in varieties that continue to have green tops in spite of infection. As such, drying of tops as a result of damage caused by the disease deserves to be reckoned as the prime factor in the evaluation of varieties for susceptibility to the disease.

2. Lesion Length *vs.* Nodal Transgression

Once the fungus has entered an internode, there is no physical barrier to its longitudinal spread from one end to the other of the infected internode. The node, characterised by a concentration of mechanical tissue, interruption in the continuity of xylem vessels (Atkinson, 1939), low content of sugars, not to mention the possible presence of fungistatic substances (Srinivasan, unpublished), constitutes a major dyke in the defences of the cane. The pathogenic potential of a clone of the fungus or conversely, the susceptibility of a host clone, is related to the facility with which the pathogen is able to break through the node. Thus, susceptibility may, in quantitative terms, be said to be related to the number of nodes that the fungus is able to cross from a single point entry rather than the lesion length *per se*. Once this is accepted, one need only cite cases like the variety Badila (Fiji B) with its very short internodes on the one hand and hybrid canes like H.M. 645 or Co.S. 245 with long internodes on the other to shew up the untenability of lesion length as against the number of nodes crossed as a criterion of reaction. Fortunately, this has now received at least partial

recognition (Chona, Sohi and Bajaj, 1960). However, to facilitate quick gradation and probably not for any particular scientific reason, these authors have chosen the average number of internodes involved in the lesion as they have found high positive correlation between lesion length and internode number in the varieties examined by them. As such a relationship is only general, their new criterion is not identical with the old one at least in the case of varieties having abnormally short or long internodes.

Apart from the fact that, in general, older canes are more susceptible than younger ones (Srinivasan, 1956), there is also wide variation in the lesion length produced in different canes of even the same age of a variety inoculated simultaneously, particularly when its resistance is one of the intermediate grades. The causes of such intra-clonal variations are only imperfectly understood.

Besides, in certain cases like the following, doubts arise as to what constitutes the lesion length; (i) often, the lesion gets narrowed beyond the inoculated internode and in extreme cases may be reduced to a thin red streak confined to a single vascular strand running through several internodes; (ii) sometimes the lesion stops abruptly at one of the nodes with spots or streaks a few internodes further on. Ought one to ignore the break in continuity of the lesion or the apparently unconnected discoloration appearing a few internodes away? Should a variety with a few hardly noticeable, broken streaks in a vista of healthy tissue leading away from the main lesion be considered equal in susceptibility to another with an uninterrupted broad lesion of the same length? In certain varieties like Maur. 55, M. 72/31, M. 73/31, and POJ. 2961 the lesion is broad, but before it invades three or four internodes, the tops begin to dry up and the canes shrink. Such varieties are obviously highly susceptible, but lesion length alone, as also to a certain extent the degree of nodal transgression, give, in the absence of consideration of other characters, a deceptive picture of relative resistance.

For the above reasons, it is difficult to rely with confidence on the comparison of the average lesion length produced in different varieties for the purpose of grading them for resistance. On the other hand, the largest number of nodes crossed would indicate better the pathogenic- level of the fungus in the host variety.

3. Lesion Width

Many varieties develop a broad lesion covering the major part of the internodal width but not necessarily a large number of internodes. Canes of varieties in which broad lesions develop appear to suffer more severe damage than those with narrow lesions with similar longitudinal spread and thus the width of lesion appears to be an equally, if not more, significant expression of tissue invasion (Srinivasan, 1961). Srinivasan (in press) has also indicated that lesion length derives most of its value from its high positive correlation (0·93) with lesion width.

To judge the extent of lesion width, the inoculated internode is obviously not a suitable locus on account of the artifact created by the high inoculum load introduced into it. In the one or two internodes immediately above it the lesion assumes its characteristic width and it is possible to see whether it tends to spread laterally or is confined to a narrow region of the ground tissue with a sharp, dark red margin.

4. Occurrence of White Spots in the Lesions

Another striking characteristic is the occurrence of transverse white spots in the lesions. In varieties which develop narrow lesions or only streaks, these are either rare or small and circumscribed and are surrounded by necrotic ground tissue of a dark colour the cells of which are filled with gummy substance. In broad lesions, the white spots are large and run in a transverse direction. The colour of the surrounding tissue is generally not dark but light red and often constitutes a mottle of dark and light coloured areas (Atkinson, 1939; Edgerton and Carvajal, 1944). Isolations made in this laboratory from the former type of lesion yielded the pathogen only rarely, while a large majority of transplants from the prominent white spots and the mottled ground tissue readily yielded the pathogenic culture. The presence and characters of white spots appear to be related generally to the width of the lesion and prominent white spots are indicative of poor resistance on the part of the host. Histological examination indicates that in the white spots the pathogen enters temporarily into a harmonious relationship with the host, characteristic of the more evolved type of parasite. However, in due course this phase may be followed by a sudden collapse of the host cells ending in the development of hollows as seen in advanced, severe infections. This behaviour is analogous to that of *Colletotrichum lindemuthianum* causing bean anthracnose (Leach, 1923).

5. Occurrence of Serial Spot Lesions or Streaks

Atkinson and Edgerton (1937) and Atkinson (1939) shewed that conidia, when introduced into the culm, could move up in the vascular stream of the cane and, lodging at random points, start secondary lesions. It has been a common experience with us to find circular spot lesions developing in the tissues of the upper internodes of inoculated canes in varieties possessing xylem vessels which are continuous from one internode to the next. The size and depth of colour of the spots vary. In relatively resistant varieties like Co. 393 or Co. 402 the serial, spot lesions are discrete, small, dark and red without a white centre. In susceptible varieties like Co. 313 or Co. 328 they are light red in colour with a white centre and tend to spread laterally and linearly to form large lesions which may coalesce. Similar findings have been reported by Edgerton and Carvajal (1944). As a proof of natural infections causing such spot lesions, 'off type' conidia have been demonstrated in the cells adjoining the vessels and their ability to cause infections has been established (Edgerton, 1959).

In the majority of varieties studied, occurrence of progressive, serial, spot lesions is associated with (1) high parenchyma susceptibility and (2) high susceptibility to nodal transgression, the latter having a high correlation with the former. An exceptional case, however, is that of Co. 1314. This variety has a high parenchyma susceptibility. On the other hand, resistance to nodal transgression by fungal hyphae appears to be of a high order, and the main lesion is impounded within the inoculated internode. But, large, progressive, serial spot lesions appear in every internode above the inoculated one and they even develop cavities at an early stage. The spot lesions spread within the internode in which they occur and the canes dry up rather rapidly. In this case, serial spots appear to have completely nullified the effects of the resistance to nodal transgression.

On the other hand, in certain other varieties where also the vessels are continuous but which possess a high degree of plasmatic resistance there is a severe reaction on the part of the parenchyma cells close to the vascular bundles resulting in dark red streaks. The gum enters the vessels and plugs them. Attempts to isolate the pathogen from such vessels have failed. A striking example of such a variety is Q. 42 in which only a number of red vascular streaks have been observed to extend from the inoculated internode up to seven internodes above, but the parenchyma appeared to be unaffected.

6. Nodal Necrosis

Usually the reddening caused by the disease is prominent in the internodal tissues, the node remaining either altogether white or partially discoloured. In some susceptible varieties the nodal tissues undergo considerable necrosis and may be deep red as pointed out by Edgerton (1959). In other varieties the nodal lesion tapers towards the upper part of the node and is triangular in longitudinal section. Such varieties are intermediate in tissue reaction (*e.g.*, C.P. 34/120, Co. 411). This reaction where it occurs has been observed to be correlated with that of the parenchyma.

7. Cavities in the Growth Ring

We have observed rarely in certain varieties, transverse cavities developing at the growth ring. In such cases, as in var. C.P. 27/108, there may be a diffuse mottling of the subjacent internode or it may be nearly white. The canes may undergo considerable rotting later on and the tops may dry up. The internodal tissues have invariably yielded the pathogen in re-isolations and in sections intra-cellular mycelium has been observed. This behaviour of the internodal parenchyma is similar to the 'white spots' discussed above. It appears to be relatively rare and occurs only among some of the extremely susceptible varieties.

8. Pith Lesions and their Spread into Parenchyma Tissues

In many varieties which form a pronounced pith at about the time of maturation, the red rot lesion advances rapidly up the pith, and the nodes do not appear to bar this movement, while the parenchyma lesion advances more slowly and is subject to nodal obstruction. In susceptible varieties, the parenchyma may be invaded from the infected pith. A striking example is variety Co. 993 which has a high degree of resistance to nodal transgression by the parenchyma lesion. But it has a large and susceptible pith and lesions spread out into the parenchyma from the infected pith in internodes other than the inoculated one. But in other varieties like Cl. 41–70, a fringe of cells bordering the pith reacts with severe necrosis and copious gum formation which is lethal to the hyphae, and the fungus is barred from attacking the parenchyma (Srinivasan, 1958). This appears to be a type of hyperergic defensive reaction (Gäumann, 1946), analogous to the hypersensitive reactions against rusts (Stakman, 1915; Thatcher, 1943). Such hyperergic reactions are known against other facultative parasites also (Schwinghamer, 1954; Flentje, 1957; Tomiyama, Takakuwa and Takase, 1958). A non-specific chemical toxin, 'phytoalexin', is believed to be involved in such reactions (Müller, 1957, 1958).

In sugarcane, both the types of resistance, *viz.*, the plasmatic which is dynamic and the structural which is static, play a part in the defences of the plant against red rot. In resistant varieties, the former is expressed by the copious production of gums in the lesions and the 'containing' process involved in the development of the 'gummed-up fringe' associated with pith lesions. Mechanical or structural resistance is located at the nodes. This comprises two kinds: (i) the ramification of vascular tissue and the heavy lignification of the ground tissue, and (ii) the extent to which septa occur in the vessels. The first bars to a greater or lesser extent the advance of the fungal hyphae across the node into the neighbouring internodal ground tissue, while the latter decides the movement of spores in the vascular stream from the lower internodes to the upper. Thus, the mechanical barrier functions in two ways: the one against the extension of the primary lesion (nodal transgression) and the other against the occurrence of secondary lesions (serial spots).

The mechanical defences determine the extent of longitudinal expansion of the lesion. On the other hand, the dynamic (plasmatic) defence reaction governs lateral (and, within the internode, longitudinal) extension of the lesion involving the sugar-bearing ground tissue. Apart from controlling the destruction of tissue, the latter has repercussions on the pnysiological effects of the disease. Not only are the fungal hyphae physically sealed off, but their enzymatic activity, *viz.*, inversion of sucrose, is also restricted. Thus, such resistance is doubly advantageous.

It should thus be clear that greater emphasis has to be placed on plasmatic resistance than on mere mechanical resistance as is sought

to be done by the more orthodox consideration of only average lesion length. Mechanical resistance as measured by the number of nodes crossed is highly variable while plasmatic resistance as indicated by the nature of the lesion is surely more dependable. However, in view of the fact that physiological processes as well as structural equipment both of which are inherited, together determine the outcome of the host-parasite interaction both types of resistance deserve to be taken into account, while laying greater emphasis on the dynamic aspect.

A critical examination of the reaction of 127 varieties in the 1957–58 season and an altogether different set of 554 varieties in 1959–60 (to the same strain of the pathogen, *i.e.*, the D strain) for all the above characters was made with a view to assess their relative importance in grading the varieties for resistance. The results (*vide* Charts 1 and 2) have shown that only the first four characters, *viz.*, (1) drying of tops, (2) lesion width, (3) occurrence and nature of white spots and (4) nodal transgression are critical and dependable. The other four are useful generally in confirming the reaction revealed by these key-characters. The latter are seen in relatively few varieties and failure to observe them in others is not indicative of any particular degree of resistance. Out of the 554 varieties of 1959–60, 77 were again tested in 1960–61 and were found to conform to their previous year's grades except for a shift of just one grade in the case of 17 varieties.

A striking peculiarity of the four principal characters is that they are highly correlated, though not corresponding in all their grades. On account of this, the two sets of varieties tested gave, in all, only 9 combinations out of the 44 that were possible (*vide* Charts). The complete identity of grades in the two cases which is to be expected on the basis of arguments presented above inspires confidence about the four characters being of universal diagnostic value.

Yellowing and drying of tops at the usual time of inspection after inoculation (which is at three months at Coimbatore) which, as will be seen from the charts, are inevitably associated with high grades of the other three characters, indicate high susceptibility. This one feature alone is deemed a sufficient criterion for this class and the other characters need not be taken into consideration. Only those that continue to carry green tops deserve sub-classification into various categories based on the other three characters. The categories actually observed have been named in the charts themselves to serve as a key in grading varietal resistance. They have been fully described separately in the suggested key forming an accompaniment.

From experience gathered over several years it seems possible that some of the varieties graded in one season according to the suggested key, when tested under different sets of conditions, either more or less adverse to the host or more or less favourable to the pathogen in another season but with the same pathogenic strain, may shift into the next category in either direction, but not any further.

GRADING OF SUGARCANE VARIETIES FOR RED-ROT RESISTANCE

CHART-I (1957-58)

LESION WIDTH X → / NATURE OF WHITE SPOT	0,0	1,0	1,1	1,2	2,0	2,1	2,2
NO. OF NODES CROSSED ↓	A. TOPS GREEN						
0	H.R.(2)						
1		R.(2)	M.R.(3)				
2-4			M.S.(29)			S.(16)	S.(6)
MORE THAN 4						S.(8)	S.(20)
	B. TOPS YELLOW OR DRY						
0							
1							
2-4							
MORE THAN 4							H.S.(41)

CHART-II (1959-60)

LESION WIDTH X → / NATURE OF WHITE SPOT	0,0	1,0	1,1	1,2	2,0	2,1	2,2
NO. OF NODES CROSSED ↓	A. TOPS GREEN						
0	H.R.(37)						
1		R.(114)	M.R.(28)				
2-4			M.S.(118)			S.(51)	S.(6)
MORE THAN 4						S.(6)	S.(34)
	B. TOPS YELLOW OR DRY						
0							
1							
2-4							
MORE THAN 4							H.S.(160)

H.R.: Highly resistant R: Resistant M.R.: Moderately resistant
M.S.: Moderately susceptible S: Susceptible H.S.: Highly susceptible

Lesion Width: 0: Lesion confined to inoculated internode
1: Lesion sharply restricted in width
2: Lesion tending to spread laterally

White spot: 0: Absent
1: Circumscribed
2: Prominent

The numbers within brackets indicate the number of varieties in each class

A cursory inspection of the charts reveals the abundant presence of resistance. Of the 554 varieties, 151 were highly resistant or resistant and 28 moderately resistant. While the resistant ones should be readily acceptable for varietal selection, caution has to be exercised in the case of the moderately resistant ones which under certain conditions may become moderately susceptible. The remaining 375 do not deserve to be considered for areas where red rot is a problem.

The frequencies recorded in the various grades according to the new classification and those obtained by the method of average lesion length for the 127 varieties tested in the 1957–58 season are presented in Table I.

TABLE I

Number of varieties falling into different categories

	By new classification	By method of average lesion length
Highly resistant ..	2	..
Resistant ..	2	9
Moderately resistant ..	3	77
Moderately susceptible ..	30	..
Susceptible ..	57	30
Highly susceptible ..	33	11
	127	127

Further, the frequencies indicative of divergence in each grade of the key as compared to the grades arrived at by the method of average lesion length are given in Table II.

It will be seen from Tables I and II that, firstly, the frequencies under different grades are very different. Secondly, there is serious divergence (of more than one grade) in classification in as many as 49 varieties of which the average lesion length method grades 44 susceptible varieties as resistant or moderately resistant, and five highly susceptible varieties as moderately resistant. That all these varieties are really susceptible or highly susceptible was confirmed by the fact that inoculated clumps of these varieties left over in the field up to five months after inoculation exhibited yellowing and drying of tops sooner or later. In view of the

TABLE II

Frequencies indicative of divergence in grades of resistance as assessed by the two methods

Proposed grades	Grades by average lesion length method				Totals
	R	MR	S	HS	
HR ..	2	0	0	0	2
R ..	2	0	0	0	2
MR ..	2	1	0	0	3
MS ..	2	28	0	0	30
S ..	1	43	13	0	57
HS ..	0	5	17	11	33
Totals ..	9	77	30	11	127

serious divergences pointed out above, the average lesion length method has not been adopted at this Institute from 1959–60 onwards.

Failure under cultivation has often been experienced of certain cultivated varieties which have given a relatively resistant reaction in artificial testing. This has been attributed to likely changes in the pathogenic flora. While this may be true, there is also the possibility that sole dependence on average lesion length in grading varieties might have led to errors in classification at least in certain cases. For example, varieties Co. 513, Co. 617, Co. S. 109 and Co. S. 443 which are reported to be succumbing to the disease in certain parts of U.P. (Anonymous, 1959), would be called moderately resistant to resistant by the average lesion length method, while they are susceptible by the criteria suggested here. On the other hand, none of the cultivated varieties graded as either resistant or moderately resistant by the method suggested by us has been reported as susceptible under cultivation.

It would thus appear that subject to any minor refinement possible in the light of future experience, the key suggested in this paper is much more suitable for assessment of red rot resistance than average lesion length used as the sole criterion.

SUMMARY

The average lesion length as a criterion of susceptibility of sugarcane varieties to red rot is unsatisfactory. Eight different characters,

representing both plasmatic and structural resistance, have been examined and their suitability as criteria has been discussed. Examination of 681 varieties indicates that four of these characters, *viz.*, drying of tops, lesion width, occurrence and nature of white spots in the lesions, and nodal transgression would be of universal diagnostic value. The combination of these four characters is dependable and is likely to reflect truly the reaction of any given variety. The other characters are generally of a confirmatory nature. A key to the grades of resistance employing these characters is presented.

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* Original not seen.

SUGGESTED KEY FOR RESISTANCE CATEGORIES

Highly resistant.—Tops green; lesion confined to inoculated internode. Serial spots and pith lesions absent.

Resistant.—Tops green; lesion crossing one node and tending to remain restricted in width with a sharp, dark red margin (1)*; white spots absent (0). Serial spots and pith lesions absent.

Moderately resistant.—Tops green; lesion crossing one node and tending to remain restricted in width; white spots circumscribed (1). Serial spots when present non-progressive or only vascular streaks present; pith lesions, when present, non-progressive.

Moderately susceptible.—Tops green; lesion crossing two to four nodes and tending to remain restricted in width; white spots circumscribed. Serial spots and pith lesions, when present, non-progressive; nodal necrosis, when present, tending to taper.

Susceptible.—Tops green; lesion crossing more than one node and tending to spread laterally to a greater or lesser extent (2); white spots circumscribed, or prominent (2) and typically running in a transverse direction. Serial spots and pith lesions when present progressive; rarely, nodal transgression nil, but serial spots and/or pith lesions progressive; nodal necrosis, when present, not tending to taper.

Highly susceptible.—Tops yellow or dry. (Lesions crossing a few nodes or more often the greater part or the entire cane and covering the greater part or the entire width of cane; white spots prominent, transverse. Serial spots and pith lesions, when present, progressive, but often not distinguishable due to coalescence of lesions; nodal necrosis, when present, covering entire node; cavities present in the growth ring of certain varieties.)

* Figures in brackets indicate grades of the concerned character as in the charts.

NOTES ON SOME SPECIES OF *CRYPTOSTICTIS*—I

By C. V. Subramanian and K. Ramakrishnan

University Botany Laboratory, Madras-5

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The genus *Cryptostictis* was established by Fuckel in 1869 to accommodate *C. hysterioides* (Fuck.) Fuck., which was originally classified by him in the genus *Hendersonia* Sacc. as *H. hysterioides* Fuck. Saccardo (1884, p. 443) gives the following description for Fuckel's genus: "Perithecia erumpentia, globosa vel depressa, pertusa, subinde spuria. Sporulae oblongae, 2-pluriseptatae, utrinque 1-aristatae, fuscae, longiuscule hyalino-stipitatae.—Est fere *Hendersonia* sed sporulis ciliatis."

The genus was listed under the Fungi Imperfecti-Sphaeropsidales-Sphaerioideae-Phragmosporae by Saccardo (1884, p. 443), by Lindau (1900, p. 374), by Allescher (1903, p. 251) and by Migula (1921, p. 351). Saccardo, Lindau and Allescher also cited the genus *Dochmolopha* Cooke (1878) as a synonym of this genus. The type species of Cooke's genus, *viz.*, *D. lonicerae* Cooke, was listed as a synonym of *Cryptostictis lonicerae* (Thuemen) Sacc., which was itself based on *Hendersonia lonicerae* Thuemen (*see* Saccardo, 1884, p. 444; Lindau, 1900, p. 374; Allescher, 1903, pp. 251, 252). Coupin (1913) also listed the genus *Cryptostictis* under the Sphaeropsidales-Sphaerioideae and cited *Dochmolopha* Corda (as *Docmolopha*) as a synonym; this author citation is obviously a mistake.

In 1904 McAlpine proposed the genus *Amphichaeta* for two Australian fungi, *viz.*, *A. daviesiae* McAlp. and *A. kennedyae* McAlp., the former on *Daviesia latifolia* and the latter on *Hardenbergia monophylla* and *Kennedya prostrata*. In proposing the genus *Amphichaeta*, McAlpine (1904, p. 118) compared it with *Cryptostictis* and stated that "in *Cryptostictis* Fckl. the spores are similar to those of *Amphichaeta* but they are enclosed in a perithecium"; McAlpine placed his genus in the Melanconiales.

Later on, however, Hoehnel (1923, p. 342) classified *Cryptostictis* in the Melanconiales and this has been followed by Clements and Shear (1931) and by Ainsworth and Bisby (1954). When Hoehnel assigned *Cryptostictis* to the Melanconiales, he did away with the only difference between *Cryptostictis* and *Amphichaeta* on which McAlpine justified his genus, *viz.*, the nature of the fructification. One would, therefore, have normally expected *Amphichaeta* being reduced to synonymy with

Cryptostictis which was established much earlier. However, this was not done; on the other hand, Hoehnel accepted both the genera. In his key to the genera of the Melanconiales (Hoehnel, 1923, p. 342) *Cryptostictis* was distinguished from *Amphichaeta* thus: *Cryptostictis* was stated to have conidia with only one basal appendage but no apical one, whereas *Amphichaeta* was stated to have conidia with one basal as well as one apical appendage. Hoehnel's key relating to these two genera has been followed by Clements and Shear (1931) also.

Recently, Subramanian and Ramakrishnan (1956 *a*) have published results of a study of type material of the type species of *Cryptostictis* and *Amphichaeta*. Both species were shown to have the same type of fructification, *i.e.*, an acervulus, and to produce similar phragmospores, each with an apical and a basal appendage. Thus, Hoehnel's disposition of *Cryptostictis* in the Melanconiales was found acceptable, but not his description of the spores of *Cryptostictis* as being 1-ciliate at the base alone. On the basis of these observations, *Cryptostictis* was accepted as an earlier valid name for *Amphichaeta* in the Melanconiales. Both the species of *Amphichaeta* described by McAlpine were transferred to *Cryptostictis*, as circumscribed by them (Subramanian and Ramakrishnan, 1956 *a*), and one species, *viz.*, *Amphichaeta grevilleae* Loos, of which type material was available for study, was also transferred to *Cryptostictis*. Of the two collections assigned to *Amphichaeta kennedyae* by McAlpine, the one on *Hardenbergia monophylla* was found to differ from *Amphichaeta kennedyae* on *Kennedya prostrata* and from *Amphichaeta daviesiae* and was, therefore, classified as a new species of *Cryptostictis*, *C. macalpinei* (as *C. macalpineae*). Other taxa now disposed under McAlpine's genus will have to be removed to *Cryptostictis* or placed in other suitable genera.

It will be pertinent here to discuss the position of the Melanconiaceous genus *Disaeta* which was established by Bonar (1928) to accommodate a parasitic fungus which he collected on leaves of *Arbutus menziesii* from California and which he named *Disaeta arbuti* Bonar. Bonar's (1928, p. 299) diagnosis of the genus was as follows: "*Disaeta* gen. nov. Melanconiaceae-Phaeophragmiae Acervuli intraepidermal or subcuticular, erumpent, discoid, black; conidia elongate, fusoid, coloured, with the end cells hyaline; bearing one hyaline bristle at each end of the conidium. Like *Hyaloceras* Dur. (*Monochaetia* Sacc.) except that there is a bristle at each end of the conidium. Differs from *Pestalozzina* Sacc. in having the central cells coloured, which places it in the Phaeophragmiae." Clements and Shear (1931, p. 384) cited *Disaeta* as a synonym under *Amphichaeta*. In the same year, Zeller (in Zeller and Deremiah, 1931) placed Bonar's fungus in *Cryptostictis*, as *C. arbuti* (Bonar) Zeller. Zeller's new combination implies that *Disaeta* is a synonym of *Cryptostictis*, although that was not so stated by him. Thus, Bonar's genus has been cited independently by Clements and Shear (1931) and by Zeller and Deremiah (1931) as a synonym of *Amphichaeta* and *Cryptostictis* respectively and our own study of authentic material of Bonar's fungus as well as his line drawings of his fungus clearly confirm this.

Regarding *Dochmolopha* Cooke (1878), we have examined Thuemen mycotheca universalis 578 ex Herb. Cooke, ex Herb. R. B. G., Kew, which is authenticated for the names *Dochmolopha lonicerae* Cooke. *Hendersonia lonicerae* Thuemen and *Cryptostictis lonicerae* (Thuemen) Sacc. This is a good *Cryptostictis* and, therefore, Cooke's genus may be accepted as a synonym of *Cryptostictis*.

On the basis of what has been stated above, in this paper *Dochmolopha* Cooke (1878), *Amphichaeta* McAlpine (1904) and *Disaeta* Bonar (1928) are considered synonyms of *Cryprostictis* Fuckel (1869).

Cryptostictis Fuckel Char. emend.

Fuckel, 1869, Fungi rhenani, 1838.

= *Dochmolopha* Cooke, 1878. in *Nuovo Giorn. bot. Ital.* **10:** 17.

= *Amphichaeta* McAlpine, 1904, in *Proc. Linn. Soc. N.S.W.* **29:** 118.

= *Disaeta* Bonar, 1928, in *Mycologia*, **20**: 299.

Fungus imperfectus, Melanconiales, Melanconiaceae, Phragmosporae.

Acervuli intraepidermal or subcuticular, erumpent, black. Conidiophores distinct, simple or branched, often long, subhyaline to pale-coloured, thin-walled, filiform. Conidia acrogenous, single, elongate, brown, septate, with the end cells paler and thinner walled than the middle ones; apical and basal cells each with one simple, filiform, hyaline appendage.

Type species:

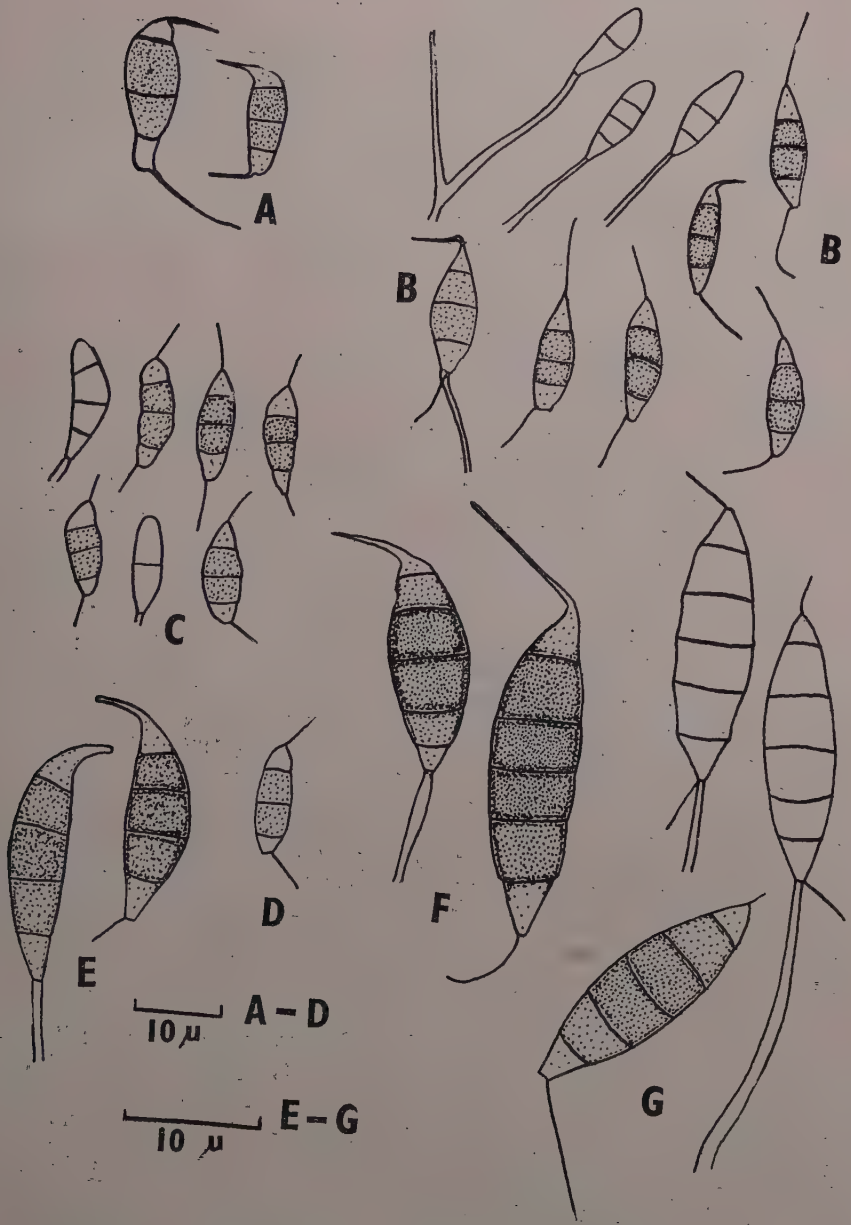
1. *Cryptostictis hysterioides* (Fuck.) Fuck., 1869, Fungi rhenani, 1838; Saccardo, 1884; *Sylloge fungorum*,

   = *Hendersonia hysterioides* Fuck., *Symb. myc.*, p. 392, Table IV, Fig. 24.

The acervuli are gregarious, elliptical to elongate, black, innate, later erumpent, and disposed in parallel series. The conidia are pedicellate, ovate, somewhat unequal, attenuate at either end, somewhat obtuse towards apex, 3-septate, rarely 1-2-septate, brown, smooth-walled, the middle cells being dark brown in colour and the end cells paler, and each with a short cilium. The conidia are 14·0–18·2 μ long and 4·2–5·6 μ wide where widest. The basal appendage is up to 10 μ long and the apical one up to 7·0 μ long (in TYPE).

The following specimens have been seen:

1. *Cryptostictis hysterioides* Fckl. Fungi rhenani 1838. Ad *Vitis viniferae* sarmentorum corticem, rarissime, Autumno. Ca Budenheim (Rheingau). Herbier Fuckel 1894. Herbier Barbey Boissier, Fungi of Germany 2329. ex Herb. U.S.D.A. (Herb. M.U.B.L. 1514—slide),



TEXT-FIG. 1. Spores of various *Cryptostictis* spp. A, *C. hysterioides* ex. Herb. M.U.B.L. 1514; B, *C. lonicerae* ex Herb. M.U.B.L. 1516; C, same, ex Herb. M.U.B.L. 1515 (type specimen of *C. physocarpi*); D, *C. cynosbati* ex Herb. M.U.B.L. 1529; E, *C. ilicina* ex Herb. M.U.B.L. 1527; F, G, *C. mariae* ex Herb. M.U.B.L. 1533 and 1528 respectively.

2. The same exsiccatum was obtained from the following sources also and examined: ex Herb. R.B.G., Kew (Herb. M.U.B.L. 1511—slide); ex Herb. New York Bot. Gard. (Herb. M.U.B.L. 1512—slide); and ex Herb. Mus. Botan. Stockholm (Herb. M.U.B.L. 1513—slide).

One specimen labelled "*Cryptostictis hysterioides* Fckl., Rio-Piedras, XII–12–15—J. A. Stevenson, 3481 Fungi of Puerto Rico" ex Herb. New York Bot. Gard. was also examined. This is not a *Cryptostictis*, but is identical with *Ciliochorella mangiferae* Sydow as redescribed by Subramanian and Ramakrishnan (1956 *b*).

Other Species:

2. *Cryptostictis lonicerae* (Thuemen) Sacc., 1884, *Sylloge fungorum*, **3**, 444; Allescher, 1903, in *Rabenhorst's Kryptogamenflora* **1**: (Abt. VII): 252.

   = *Hendersonia lonicerae* Thuemen. Mycotheca universalis No. 578 (non *H. lonicerae* Fries, 1846, *Summa Veg. Scand.*, p. 146) *see* Saccardo, 1884, *Sylloge fungorum*, **3**: 423.

   = *Dochmolopha lonicerae* Cooke, 1878, *Nuovo G. bot. Ital.* **10**: 25.

   = *Cryptostictis physocarpi* Vestergren, 1899, *Bot. Notiser*, **1899**: 166; Saccardo, 1902, *Sylloge fungorum* **16**: 947; Migula, 1921, *Kryptogamenflora* **3** (Teil 4, Abt. 1): 361.

Hendersonia lonicerae Thuemen was distributed by Thuemen in his Mycotheca universalis no. 578. Thuemen's binomial is a later homonym of *H. lonicerae* Fries (1846). In 1878, Cooke published his "Praecursor ad monographiam Hendersoniae" wherein he erected a new genus *Dochmolopha* based on Thuemen's specimen which he called *D. lonicerae* Cooke. It would appear that Thuemen's Mycotheca universalis 578 distributed *sub. Hendersonia lonicerae* Thuemen is authenticated for the names *H. lonicerae* Thuemen and *Dochmolopha lonicerae* Cooke. Later, Saccardo (1884, p. 444) removed the fungus to the genus *Cryptostictis* as *C. lonicerae* (Thuemen) Sacc. In doing so, Saccardo added after the description: "Nuclei definiti globosi, sed membrana perithecii imperfecta".

Saccardo's (1884) description of the fungus was as follows: "Perithecis innato-erumpentibus, globoso-depressis, spuriis, nigris, haud papillatis, seriatis; sporulis breve fusoideis, 3-septatis, 12–15×4 (sine ciliis), loculis interioribus olivaceous, extimis hyalinis oblique aristatis, aristis hyalinis, 10–15×1; pedicellis filiformibus, saepe ramosis, praelongis 30–40 μ longis, hyalinis. Hab. in ramulis corticatis *Lonicerae tataricae*, Bayreuth in Bavaria."

Fifteen years later, Vestergren (1899) reported a fungus which he collected on *Physocarpus opulifolius* and *P. amurensis* from the Botanical Garden at Uppsala, Sweden and which he believed to be the same as *Hendersonia lonicerae* Thuemen (nec. de Not.) [= *Cryptostictis loni-*

cerae (Thuem.) Sacc.]. Vestergren appears to have considered the substratum of Thuemen's fungus to be *Physocarpus opulifolius* and not *Lonicera* and, therefore, he proposed the new name *Cryptostictis physocarpi* for Thuemen's fungus. Vestergren's nom. nov., however, cannot be accepted under the Rules and is, therefore, cited here as an obligate synonym of *Cryptostictis lonicerae*.

We have examined Thuemen's Mycotheca universalis no. 578 which is authenticated for the name *Cryptostictis lonicerae*. The fructification is acervular in nature, black and innate-erumpent. The conidiophores are simple or branched, hyaline, filiform, thin-walled, up to about 30 μ long and about 1 μ wide. The conidia are short-fusiform, usually 3-septate (rarely 5-septate), hyaline when young, brown when mature, produced acrogenously and singly on conidiophores and conidiophore branches, mostly 14·0–15·4 μ long, about 4·2 μ wide where widest, with the middle cells dark brown in colour and the apical and basal cells paler coloured and almost subhyaline. The apical cell of the conidium has a simple, filiform, hyaline appendage at its tip and this appendage may be 4·2–9·8 μ long. The basal cell of the conidium has a similar appendage arising from one end of its basal scar and therefore appears eccentric; this appendage is also filiform and 4·2–9·8 μ long. The appendages may be straight or curved or bent. Some stages in conidial formation have been seen and are figured in the text.

One specimen labelled "*Hendersonia lonicerae* (Fr.) Sacc." on *Lonicera periclymenum*, C. Roumeguere, Fungi selecti exsiccati 6430 (Fungi of France) ex Herb. New York Bot. Gard. (Herb. M.U.B.L. 1518—slide) was also examined. The conidia are phragmospores produced singly and acrogenously on conidiophores and possess a filiform, somewhat caudate, short or long, apical appendage, but they do not have a basal appendage. The specimen is not a *Hendersonia*; nor is it a *Cryptostictis*, as defined in this paper.

A third specimen labelled "*Hendersonia lonicerae* De Not. f. *Lonicerae tatarica* Bavaria. Bayreuth 476 leg. de Thuemen 45 ex herb. de Thuemen Fungi of Bavaria" ex Herb. New York Bot. Gard. (Herb. M.U.B.L. 1517—slide) was also examined. The fructification is acervular. The conidia are phragmospores produced acrogenously and singly; they do not possess any appendages and for this reason the specimen cannot be placed in *Cryptostictis*.

We have also examined Vestergren's collection sub *Cryptostictis physocarpi* on *Physocarpus* ex Herb. U.S.D.A. (Herb. M.U.B.L. 1531—slide) and ex Herb. R.B.G., Kew (Herb. M.U.B.L. 1515—slide). The labels carry the words, "in ramulis siccis *Physocarpi opulifolii et amurensis*", but we are not sure of the species for each of these two exsiccatae. A description of Vestergren's fungus based on a study of the material is given below.

The acervuli are black and innate-erumpent. The conidiophores are hyaline, simple or branched, of variable length, filiform and about 1 μ wide. The conidia are somewhat fusiform, widest in the middle,

straight or sometimes slightly curved, 3-septate, 11–16 μ long, 3·5–4·2 μ wide in the middle, with the two middle cells thick-walled and brown in colour, and the end cells thin-walled and hyaline to subhyaline. Each conidium has an apical and a basal appendage. The apical appendage arises at the tip of the apical cell, is filiform, straight or bent and 5·6–9·8 μ long.

A comparison of the above description with that of *Cryptostictis lonicerae* (Thuem.) Sacc. shows that both fungi are similar and therefore Vestergren's collection may be disposed under *C. lonicerae*.

3. *Cryptostictis ilicina* (Sacc.) Sacc., 1884, *Sylloge fungorum* **3**: 443–444; Allescher, 1903, *Rabenhorst's Kryptogamenflora*, **1** (Abt. VII): 252; Migula, 1921, *Kryptogamenflora*, **3** (Teil 4, Abt. 1): 361.

   = *Pestalozzia ilicina* Sacc., 1876, *Nuovo G. bot. Ital.* **8**: 198.

This fungus was first described as a *Pestalotia* (*Pestalozzia*) by Saccardo (1876) and was later removed by him to *Cryptostictis* (Saccardo, 1884, p. 443). Saccardo (1884) gave the following description: "Maculis exaridis, albidis, angulosis; pseudoperitheciis lentiformibus, membranaceis, astomis, erumpentibus; sporulis ovoideis, 15 × / μ, 5 locularibus loculis extimis oblique l-aristatis, hyalinis, ceteris fuligineis stipite filiformi, 30 × 1·75 μ, hyalino. Hab. in foliis languidis *Quercus Ilicis*, Arco (Trentino) in Italia boreali."

Saccardo's Mycotheca veneta no. 327 is authentic for this name and the exsiccatum ex Herb. U.S.D.A. (Herb. M.U.B.L. 1527—slide) is labelled: *Cryptostictis ilicina* Sacc. (sub) *Pestalozzia ilicina* Sacc. Arco (Trentino) in foliis languidis *Quercus Ilicis*, Sept. 1874. It also bears the following note: *Pestalozzia ilicis* West (?) West in *Bull. Ac. Scienc. Bru.*, 1859, **7**: 366, f. 21 (mihi ignota). We have examined Mycotheca veneta no. 327. It consists of three leaves with spots. The spots are yellowish-wnite, angular and irregular. The acervuli are scattered in the spots; they are separate, black, erumpent and somewhat circular to irregular. The conidophores are hyaline, thin-walled, filiform, simple, up to about 20 μ long and about 1·5 μ wide; they arise from a basal stratum of brownish, polygonal cells. The conidia are produced singly and acrogenously at the tip of the conidiophores and are somewhat fusiform, widest in the middle, with a definite convexity on one side, showing a slight but distinct curvature, typically 4-septate (septa somewhat equidistant), 14–18 μ long, and 4·2–4·9 μ wide in the middle. The three middle cells are dark brown in colour and thick-walled, whereas the end cells are hyaline to subhyaline and thin-walled. The apical cell of the conidium is prolonged into a prominent beak-like, filiform appendage 1·4–2·8 μ long. The basal cell has a filiform appendage arising from a point on the flat scar and directed away from the concave side of the spore; this appendage is 1–2 μ long.

This is a good *Cryptostictis* and the 4-septate conidia distinguish it from *C. hysterioides* and *C. lonicerae*, both of which have typically 3-septate conidia.

4. *Cryptostictis cynosbati* (Fuck.) Sacc., 1884, *Sylloge fungorum* **3**: 443; Allescher, 1903, *Rabenhorst's Kryptogamenflora*, **1** (Abt. VII): 252–53, ic.; Magula, 1921, *Kryptogamenflora* **3** (Teil 4, abt. 1): p. 361, ic.; Coupin, 1913 (?), *Album General des Cryptogames* (Fungi Imperfecti), Plate 332, Fig. *b*.

= *Hendersonia cynosbati* Fuckel, 1869, *Symb. myc.*, p. 392, Tab. IV, Fig. 23.

= *Discosia cynosbati* Fuckel, Fungi rhenani 455.

Saccardo (1884, p. 443) gives the following description:

"Peritheciis spuriis hemisphericis, atris, tectis, demun erumpentibus; sporulis pedicellatis oblongis, utrinque parum attenuatis verotundato-obtusis, curvatis, 3-septatis, pallide flavis, 14–15 × 5–6 μ utrinque sub apice ciliis sporula sublongioribus. Hab. in fructibus siccis adhuc stantibus *Rosae pimpinellifoliae* vel *spinosissimae* in Rhenogovia et Bavaria."

We have examined Fuckel, Fungi rhenani 455 (sub. *Discosia*), ex Herb. U.S.D.A. (Herb. M.U.B.L. 1529—slide), which may be considered authentic for the name. There is hardly any fungus left on the material, but one spore was seen which is figured. The spore is fusiform, dorsiventral, widest (4·2 μ) in the middle, 12·6 μ long, 3-septate (septa equidistant), with the middle two cells brown in colour and the two end cells hyaline. The apical and basal cells have simple, straight, short, filiform appendages 4·5–5·6 μ long; the basal cell of the conidium has a flat scar indicating point of attachment to conidiophore and the basal appendage arises from one end of the scar.

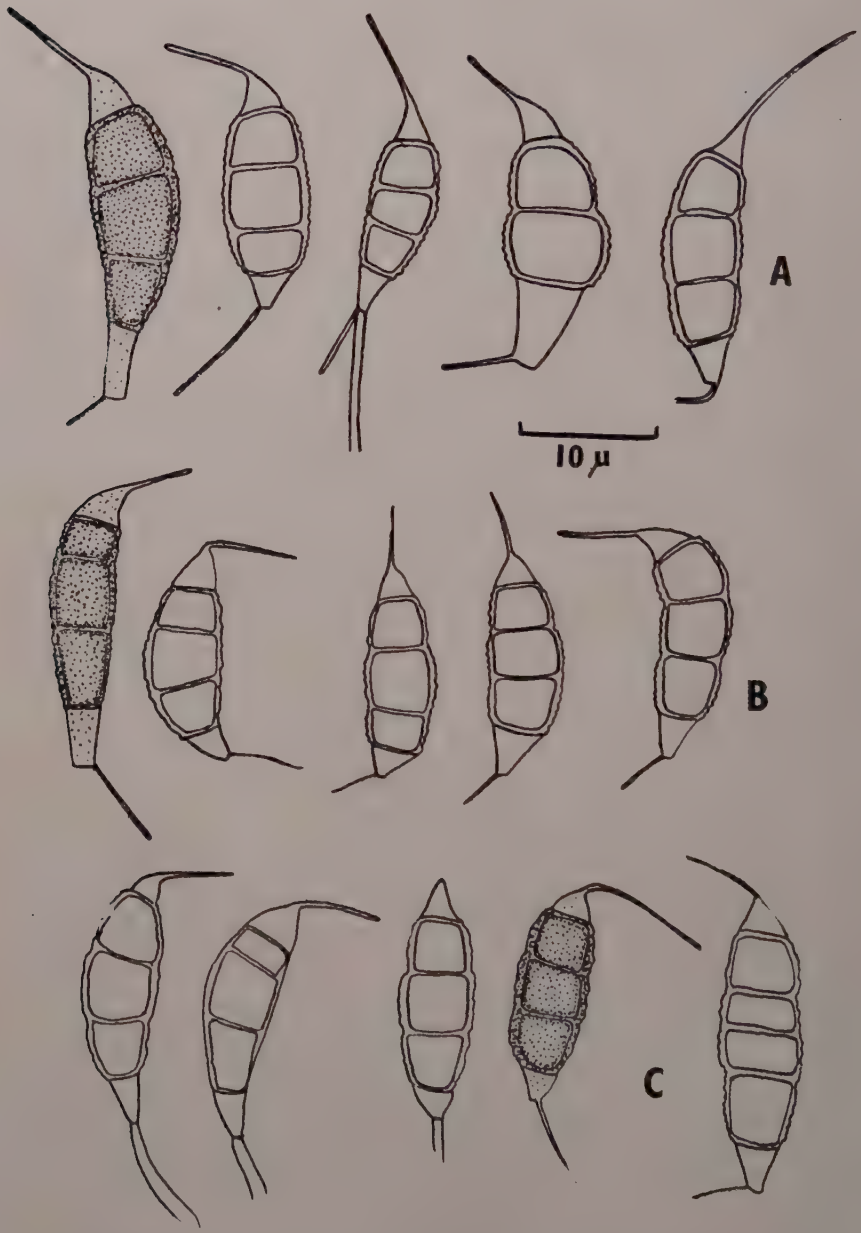
One other specimen, de Thuemen, Fungi austriaci 1061 on *Rosa pimpinellifolia* sub. *Hendersonia cynosbati* Fckl., ex Herb. U.S.D.A. (Herb. M.U.B.L. 1530—slide) was examined, but no spores were seen.

We believe that, in all probability, *Hendersonia cynosbati* Fckl. and *Discosia cynosbati* Fckl. may be earlier names for *Hendersonia lonicerae* Thuemen. However, in view of the imperfect condition of the material (Fuckel, Fungi rhenani 455) seen, *Cryptostictis cynosbati* and *C. lonicerae* are retained separately here. It is noteworthy that a nom. nov., *C. physocarpi* (which is considered in this paper an unnecessary and hence superfluous name for *C. lonicerae*) was proposed by Vestergren (1899) for *Hendersonia lonicerae* Thuemen, which according to him occurred on the Rosaceous genus *Physocarpus* and not on *Lonicera*.

5. *Cryptostictis mariae* (Clinton) Sacc., 1884, *Sylloge fungorum* **3**: 444.

= *Pestalozzia mariae* Clinton, in Peck, *Rep. State Mus. N.Y.*, t. 2, Figs. 1–2.

The fungus was first described as a *Pestalozzia* by Clinton, but Saccardo (1844) removed it to *Cryptostictis*. Saccardo (1884, p. 444)



TEXT-FIG. 2. Conidiophores and conidia of *Cryptostictis arbuti*. A, B, C, ex Herb. M.U.B.L. 1521, 1523 and 1524 respectively.

gave the following description: "Maculis aridis, brunneis vel cinerescentibus, brunneo-marginatis; pustulis (peritheciis) minutis, sparsis, erumpentibus, nigris, cuticula stellatim rupta cinctis; sporulis fusiformibus, 5-septatis, loculis 4 intermediis fuligineis, loculis extimis hyalinis aristatisque, 17–25 μ long (sine aristis). Hab. in foliis *Rhododendri maximi*, Buffalo et Forestburgh in Amer. bor."

The fungus is associated with a leaf spot of *Rhododendron californica* and other species of *Rhododendron* in the United States. In the Pacific north-west, the fungus causes a characteristic leaf spot of *R. californica* (Zeller, 1934). The spots are brown, lighter in colour towards the centre, giving a "bull's eye" effect. This is heightened by the development of concentric zones of acervuli of the fungus on the spot. The spots are 4–25 mm. in diameter and when abundant mars the beauty of the beautiful wild shrub.

Unfortunately, type material of this species has not been available to us for study. However, the following collections have been seen:

(1) on *Rhododendron californicum* [socio *Chrysomyxa piperiana*, (Arth.) Sacc. and Trott.], Hecctta Beach, Lincoln Co., Ore., May 31 1936. Coll. B. F. Dana, Det. R. Sprague, O.S.C. 220, ex Herb. U.S.D.A. (Herb. M.U.B.L. 1528—slide); (2) on *Rhododendron* sp., Andrews Bald, Gt. Smoky mts., Nat. Park, Tenn. October 17, 1940, coll. and det. E. K. Cash, ex Herb. U.S.D.A. (Herb. M.U.B.L.1533—slide); (3) on *Rhododendron macrophyllum*, Couperville, Island Co., Wash., December 6, 1931, coll. K. Baker, AS 20926 ex, CS no. 2124, ex Mycological Herbarium, Dept. of Plant Pathology, State Coll. of Washington, ex Herb. U.S.D.A. (Herb. M.U.B.L. 1534—slide); (4) on leaves of *Rhododendron macrophyllum* (*R. californicum*) Summit beyond Loon Lake, Douglas Co., coll. L. N. Goodding, det. S. M. Zeller, ex Herb. New York Bot. Gard. (Herb. M.U.B.L. 1914—slide).

The spots are brown and paler towards the centre. The acervuli are small, innate-erumpent and black. The conidiophores arise from a basal stratum of brownish cells and are mostly simple, hyaline, filiform, 14–28 μ long and 1–3 μ wide. The conidia are fusiform, widest in the middle and narrowing towards either end, straight, typically 5-septate with the 4 middle cells thickened and dark brown in colour and the end cells thin-walled and hyaline to subhyaline, 16·8–25·2 μ long, 5·6–7·7 μ wide in the middle, and produced singly and acrogenously on the conidiophores. The basal and apical cells of the conidium are 3·5–4·2 μ wide. Each conidium bears one simple, filiform appendage 2·6–14·0 μ long at its tip, and another similar appendage 5–11 μ long at the base; this basal appendage arises from one end of the flat basal scar of the conidium.

The fungus is a good *Cryptostictis*. It comes very close to *C. arbuti*, discussed later in this paper, but in *C. arbuti* the conidia are typically 4-septate and are only rarely 3- or 5- septate.

According to Zeller (1934), *C. mariae* is undoubtedly the species which Schmitz (1920) has mentioned as a cause of a leaf spot of *Rhododendron* and it is the disease which has usually been referred to as the *Coryneum* leaf spot caused by *Coryneum rhododendri* Cooke.

6. *Cryptostictis arbuti* (Bonar) Zeller in Zeller and Doremiah, 1931, *Phytopathology* **21**: 972; Zeller, 1934, *Mycologia* **26**: 300.

= *Disaeta arbuti* Bonar, 1928, *Mycologia* **20**: 299–300, ic.

This fungus was first described by Bonar in 1928 as the type of his new genus *Disaeta*. Bonar's (1928, pp. 299–300) description of the fungus was as follows: "Spots irregular in outline, often becoming several centimetres in diameter and involving the major portion of the leaf, dark brown with a purplish black border, which is more evident above. Spots tend to break up and fall out in angular pieces. Acervuli epiphyllous, scattered, often concentrically arranged, 0·25–0·5 mm. in diameter and becoming confluent; intra-epidermal, erumpent by the breaking of the cuticle. Conidia abundant, fusoid, slightly curved, typically 5-celled, the end cells hyaline, the central ones sub-opaque. Each of the terminal cells set with one bristle-like hair, averaging 7 microns in length. Conidia 18–26×4·5–7 microns; conidiophores simple, one-half the length of the conidia (*see* Fig. 2). Parasitic on the leaves of *Arbutus menziesii* Pursh., Mt. Tamalpais, Marin Co., and Oakland, Cal., Jan. 1923."

We have not seen type material of this fungus; however, one specimen on *Arbutus menziesii* collected and determined as this species by Lee Bonar in 1935 has been seen ex Herb. U.S.D.A. (Herb. M.U.B.L. 1523—slide) and this may be considered authentic for the name. In general, this collection answers well to Bonar's description of the species. The conidiophores are much longer than described by Bonar, being up to 21 μ long; they are filiform, thin, 1–2 μ wide, non-septate and hyaline. The conidia are somewhat fusiform, widest in the middle, distinctly dorsiventral with almost always a distinct curvature, typically 4-septate, 18·2–23·8 μ long, 5·6–7·0 μ where widest, with the three middle cells thickened and dark brown in colour, and the end cells hyaline. Each conidium has a simple, filiform, thin apical appendage which is up to 7 μ long and a similar appendage arising from one end of the flat basal scar of the conidium; this basal appendage is about 5·6 μ long.

Two other collections have also been examined: (1) on *Arbutus menziesii*, Smith River, Del Norte Co., Calif., May 1933. Coll. and det. H. E. Parks 3990 ex. 66975 U.S.D.A. Bureau of Plant Industry, ex Mus. Botan. Stockholm (Herb. M.U.B.L. 1521—slide); (2) on *Arbutus menzeisii* Pursh., Smith River, Del norte county, California, April 1933, coll. Harold E. Parks 4399 ex Herb. U.S.D.A. (Herb. M.U.B.L. 1524—slide).

C. arbuti bears a close resemblance to *C. mariae*; both occur on Ericaceous hosts, the former on *Arbutus* and the latter on *Rhododendron*.

The range in size of the conidia in both species appears to be the same. Nevertheless the two species are provisionally maintained here since in *C. arbuti* the conidia are typically 4-septate, whereas in *C. mariae* they are typically 5-septate. It is not unlikely that a more thorough study of these fungi on *Rhododendron* and *Arbutus* may bring out a wider range of variation for both species and, if this happens, there would then be sufficient reason to merge these two species into one.

C. arbuti has been reported to be associated with a leaf spot not only of *Arbutus menziesii*, but also of *Ledum glandulosum* (Ericaceae) and of *Arctostaphylos columbiana* (Ericaceae) in Oregon, U.S.A. (Zeller, 1934). The leaf spots on *Ledum* and *Arctostaphylos* are mostly circular, sometimes occupying a whole leaf tip, 5–12 cm. wide, and zonate. The central zone is grayish to light brown and the marginal ones dark brown, fringed with purplish tones. Zeller (1934) stated that the fungus itself is as found on *Arbutus*, although the setae of the spores are more flexuous in specimens from *Arbutus* where they are often as long as the spores. According to him, on all three hosts the spores are constantly 4-septate. Wagener *et al.* (1951) reported considerable damage to *Arbutus menziesii* due to the fungus in California.

7. *Cryptostictis paeoniae* Tehon and Daniels, 1925, *Mycologia* **17**: 243–44, ic.

Tehon and Daniels (1925) described the fungus as follows: "Spots variable in size, 1–10 mm. in diameter, round to oval, tan to brown, definitely limited by a raised concolorous margin. Pycnidia black, spherical, papillate-roughened, semi-erumpent, 75–120 μ in diameter; ostiole 10 μ wide. Spores hyaline to greenish, 3-septate, nearly straight to falcate, 14–15 $\times$ 4–5 μ, walls of central two cells distinctly heavier; setae one to each terminal cell, hyaline, 3–4 μ long. On leaves of *Paeonia officinalis*. Bloomfield, Johnson County, Illinois, July 25, 1922. Acc. No. 6024 (Type); Tampico, White County, August 15, 1922. Acc. No. 2065." Tehon and Daniels added: "*Monochaetia paeoniae* (Maubl.) Sacc. and D. Sacc., which produces its acervuli on the branches of *Paeonia arborea*, has many characteristics common with our species; and the two may be, as is true of other "Imperfecti", variations of the same fungus. We have not seen intergrading forms in connection with our species, however, and therefore prefer to record it separately."

We have examined type material of this fungus, ex Herb. U.S.D.A. (Herb. M.U B.L. 1526—slide) and find that it is not a *Cryptostictis*. We consider that this fungus should be placed in the genus *Discosia*, but pending taxonomic studies of that genus, a new combination in *Discosia* is not proposed here.

8. *Cryptostictis violae* Tehon and Daniels, 1925, *Mycologia* **17**: 245, ic.

Tehon and Daniels (1925) described the fungus as follows: "Spots large, diffuse, yellow or tan, unlimited except by the veins, circular to oval, 0·5–1·5 cm. or more in diameter. Pycnidia abundant scattered

but most numerous toward the periphery of the spot, flask-shaped, the ostiole extruded or often the upper half of the pycnidium erumpent, dark brown, parenchymatically reticulate, 60–80 μ in diameter. Spores hyaline, 3-septate, often slightly curved, 2·2–3·5 × 14–16 μ. Bristles of the terminal cells hyaline, slightly curved, filiform, 8–10 μ long. On leaves of *Viola* sp., Rushville, Schuyler County, Illinois, July 13, 1922. Acc. No. 16631 (type)."

We have examined type material of the fungus ex Herb. U.S.D.A. (Herb. M.U.B.L. 1525—slide) and find that, like *Cryptostictis paeoniae*, *C. violae* also should be classified in the genus *Discosia*. Pending taxonomic studies on *Discosia*, a formal transfer involving a new combination is not made here.

Summary

The results of a study of some species of the genus *Cryptostictis* Fuckel are presented in this paper. Following Hoehnel, *Cryptostictis*, as typified by *C. hysterioides* (Fuckel) Fuckel, is considered to belong to the Melanconiales. The conidia are phragmospores with one simple, filiform appendage arising from each end of the conidium; they are produced singly and acrogenously on simple, branched, filiform conidiophores. The middle cells of the conidia are usually darker and thicker walled than the end cells. Besides the type species, eight others now classified in *Cryptostictis* were studied from type, authentic or other material. Of these, *C. lonicerae* (Thuemen) Sacc., *C. ilicina* (Sacc.) Sacc., *C. cynosbati* (Fuck.) Sacc., *C. mariae* (Clinton) Sacc., and *C. arbuti* (Bonar) Zeller are provisionally retained in the genus as good species. *C. physocarpi*, which was proposed as a nom. nov. for *C. lonicerae* by Vestergren, is considered superfluous and unnecessary and is reduced to synonymy with *C. lonicerae*. It is suggested that *C. paeoniae* Tehon and Daniels and *C. violae* Tehon and Daniels should be removed from *Cryptostictis* and placed in the genus *Discosia* Lib.; pending further study on the taxonomy of the genus *Discosia*, no new combinations are, however, proposed.

Acknowledgements

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ECOLOGY OF GRASSLANDS OF SAGAR, MADHYA PRADESH*

I. Grassland Map of the Area on Physiognomic Basis

By S. C. Pandeya‡

Department of Botany, Science College, Raipur

(Received for publication on May 17, 1960)

Introduction

In Ecology we try to understand the dynamics of the causal relations existing between a plant community or a single plant and its environment. Plant sociology, the science of plant community or the knowledge of vegetation in the widest sense, includes all phenomena which touch upon the life of plants in social units. This science has been investigated hitherto on five lines, *viz.*, structure of community (community composition); dependence of communities on its environment; development of community; its distribution and grouping the communities into social units and arrangement of these units—Braun Blanquet (1932). At the same time we have to bear in mind that phylogenetic processes operate through a number of systems and meet the challenge of environment with various degrees of success by achieving a measure of fitness—Dansereau (1957).

Importance of grasslands has been recognised not only in grazing but also in controlling erosion and in maintaining and building soil fertility. In grassland ecology much emphasis has been laid on the characteristics of community composition.

In the present investigations an attempt has been made to present the characteristics of grasslands of Sagar, Madhya Pradesh, on phytosociological basis and to evaluate their status under the existing conditions of the environment. Actually, the climate of Sagar supports the growth of mixed dry deciduous forests since the rainfall is good and water is stored up in the soils for absorption by deep-rooted plants. However, extensive grasslands appear in the area during monsoon which gradually disappear during the successive dry periods. These grasslands have come up in areas denuded of forests. It is obvious, therefore, that grasslands in the forest climate of the area are maintained by anthropogenic factors, especially cutting, grazing by domestic animals and fires. Whyte (1957) has made similar observations regarding the status of Indian grasslands.

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* The investigations form a part of Ph.D. thesis accepted by the University of Saugar, Sagar (M.P.), where the work was conducted.

‡ Present Address: University School of Sciences, Ahmedabad-9.

The study, which is first of its type in India, has been prosecuted on the following lines:

(1) *Composition of grasslands.*—The interaction of the existing environmental complex changes the floristic structure from place to place, habitat to habitat and season to season. In order, therefore, to have a full phytosociological data and to know the status of grasslands a study on quadrat basis was found essential. With this knowledge explanations can be offered for evaluation of communities, their growth and behaviour. This was followed by preparation of a grassland map in the field.

(2) *Edaphic factor.*—Although the present grasslands of Sagar are the product of biotic operations yet a definite effect of soil and topographic factors in the local distribution of communities is not to be denied. Therefore, soils from different grassland associations were analysed and results have been correlated wherever possible.

(3) *Succession in grasslands.*—A study of the distribution of the grassland communities in relation to soil and other factors naturally leads to an understanding of their development. The same has been described elsewhere (Pandeya, 1951–52).

The investigations were conducted during 1950–53, however, the present series of papers is a highly modified form in light of recent developments.

It is proposed to present the work in three parts:—

Part I.—Grassland map of the area on physiognomic basis.

Part II.—Composition of the grasslands.

Part III.—Edaphic factors in the distribution of grassland associations.

Situation, Topography and Climate

The investigations are based upon the grasslands lying in the suburb to the east of the city of Sagar. Sagar lies at Lat. North 23° 50′, Long. East 78° 40′ and is about 575·4 metres above sea-level.

The area is characterised by undulating plateaux (*see* Map 1). Thus there are valleys, lowlands, slopes and plateaux in the area. The grasslands are found in between cultivated fields and forests and comprise hay plots and grazed grasslands. Cultivation and grazing are continuously and effectively shaping the plant communities. However, the hay plots are fenced with thorny bushes. The grazing intensity differs from place to place due largely to differences in plant cover and animal population. Thus uplands, with no cultivation and high intensity of grazing have poor grasslands; slopes, with thin soil and less accessible to grazing animals, again are poor in vegetation; of the lowlands some are under cultivation and others are kept fenced for

hay. Grazed grasslands in the lowlands also occur in the area. There are seven villages inside this area each with an average area of 1·5 sq. kilometres. A total area of about 75 sq. kilometres under grasslands has been studied.

The underlying rock is 'basalt', locally known as 'Deccan trap'.

Climate.—The climate of Sagar is marked for wet and dry periods. Rainy season starts from the beginning of June or so and lasts till the end of September each year.

Rainfall.—The total average rainfall for the years 1951 and 1952 (years during which the work was done) is 1,149 and 1,056 mm., respectively. Of this about 180 mm. is received in June, 406 mm. in July, 305 mm. in August, 204 mm. in September and 25 mm. in October. Average rainfall for the rest seven dry months is about 76 mm., which occurs mostly in December and January. According to local Gazetteer the highest rainfall ever recorded at Sagar is 3,048 mm. in 1859 and minimum 430 mm. in 1892.

Temperature.—January is the coldest month with 11·1° C. as the mean minimum and 25° C. as the mean maximum temperatures. In the hottest month of May the mean minimum and maximum temperatures are 24·3° and 40·5° C. respectively. The highest temperature ever recorded, according to local Gazetteer, is 45·5° C. on 11th June 1897 and lowest 3·9° C. on 9th February 1893.

Climatic seasons.—Rainy season extends from June till the end of September. August is typical of the rainy season when the mean minimum temperature is 22·2° C. and the mean maximum is 27·3° C. But the optimum period of plant growth is in September when the soil and the atmosphere are sufficiently moist and there is abundance of sunshine.

This merges into winter season, commencing from the middle November to the end of February. Rainfall is very low. Temperature for the month of January (typical month) has already been given.

Summer starts from the middle of March and lasts up to June. The typical month is April. It is characterised by strong winds, no rains and scorching sun. The hottest month is May.

Grassland Map of the Area on Physiognomic Basis

A study of the analytic and synthetic characters of any grassland community in relation to environment is a foremost necessity before starting to give the principles concerned in its formation. In nature, individuals of a species are usually grouped into populations, and populations of different species may be intermingled—Hanson (1958). The ratio of population mixture varies from habitat to habitat, since some plants may be more successful than others in one habitat and some others in other habitat. This is largely governed by phylogenetic and physiological characteristics of the species—Dansereau (1957).

Incidentally this study on the grasslands of Sagar gave an opportunity to examine the methods of analytic and synthetic characters applied elsewhere.

The present study is under 'community approach'. Community approach has been considered from two view-points, one, as illustrated especially by Clements (1916, 1934 and 1936) in which succession has been emphasized, and the other in which composition has been considered, that is the kind and relationship of the organisms within individual communities. Hanson (1950) describes these two as largely a matter of emphasis because neither view-point excludes the consideration of the other.

In starting to analyse the grasslands, they were first classified into associations. Association concept has been reviewed in detail by Dansereau (1957), Hanson (1958), Pandeya (1960) and others and it is not intended to discuss the same here. Gleason's (1939) 'individualistic concept' appears more applicable for Indian vegetation. Misra and Puri (1954) have supported the same. In 1951, Curtis and McIntosh have modified Gleason's concept of little continuity between individual stands and have developed the idea of " Continuum " involving gradual variation from stand to stand. A little broader aspect of this modification has been applied in the present studies. It has been found useful to recognise and differentiate associations on their physiognomy as though differentiated from an aeroplane. This enables the observer to make a rapid survey. The important criterion taken is apparent similarity of physiognomy. On this basis the associations are being named after their dominant and co-dominant species. In the area there are zones showing the presence of a certain association and surrounding intermixing zones where species of surrounding associations overlap.

In all, the following eight grassland associations have been recognised in the area. Variants and intermixing zones have been included in the respective associations. The associations are:—

1. *Themeda quadrivalvis* association: kept fenced for hay; and mainly occupying lowlands.

2. *Cymbopogon martinii* and *Eulalia trispicata* association: kept fenced; and growing in lime-rich soils in lowlands.

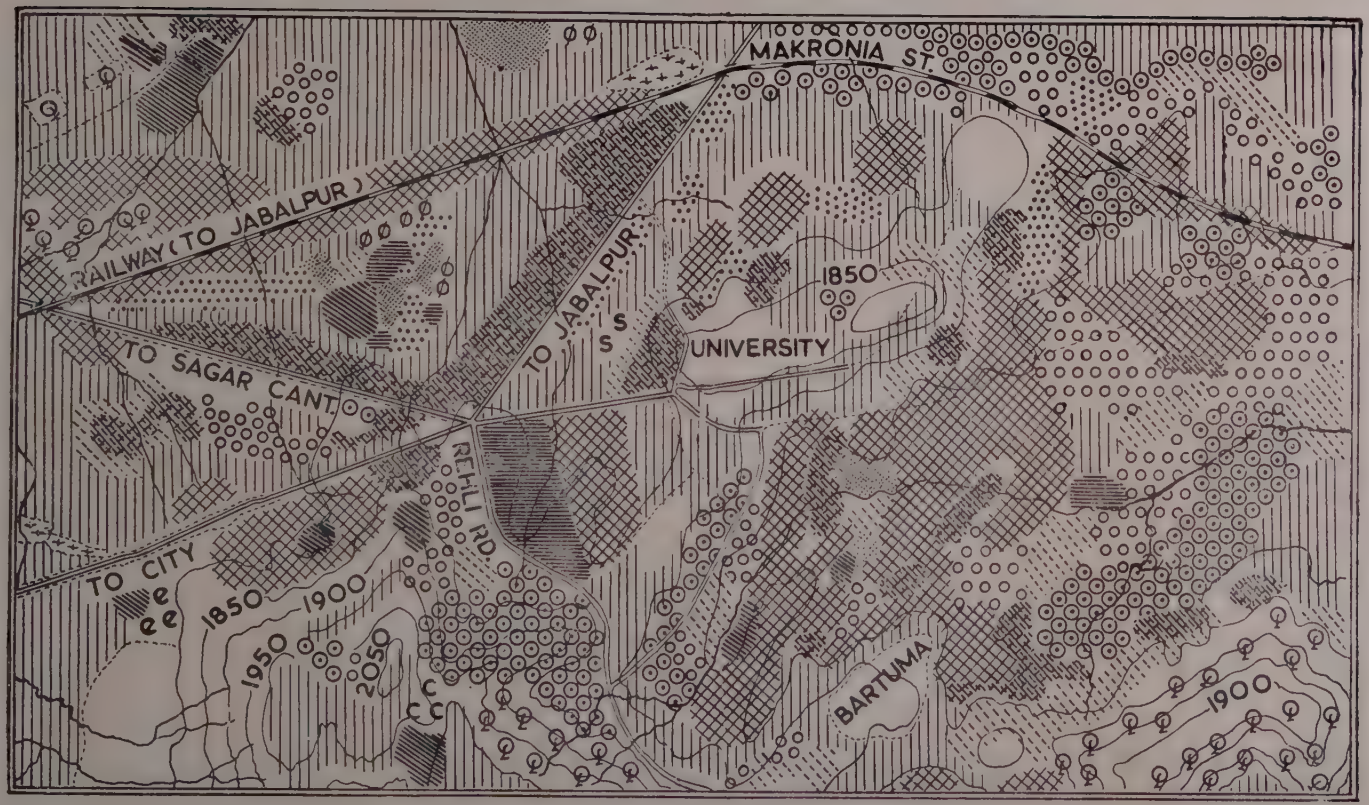
3. *Sehima nervosum—Chrysopogon fulvus* and *Tripogon lisboae* association: kept fenced; and growing mainly on lime-rich coarse soils on gradual slopes.

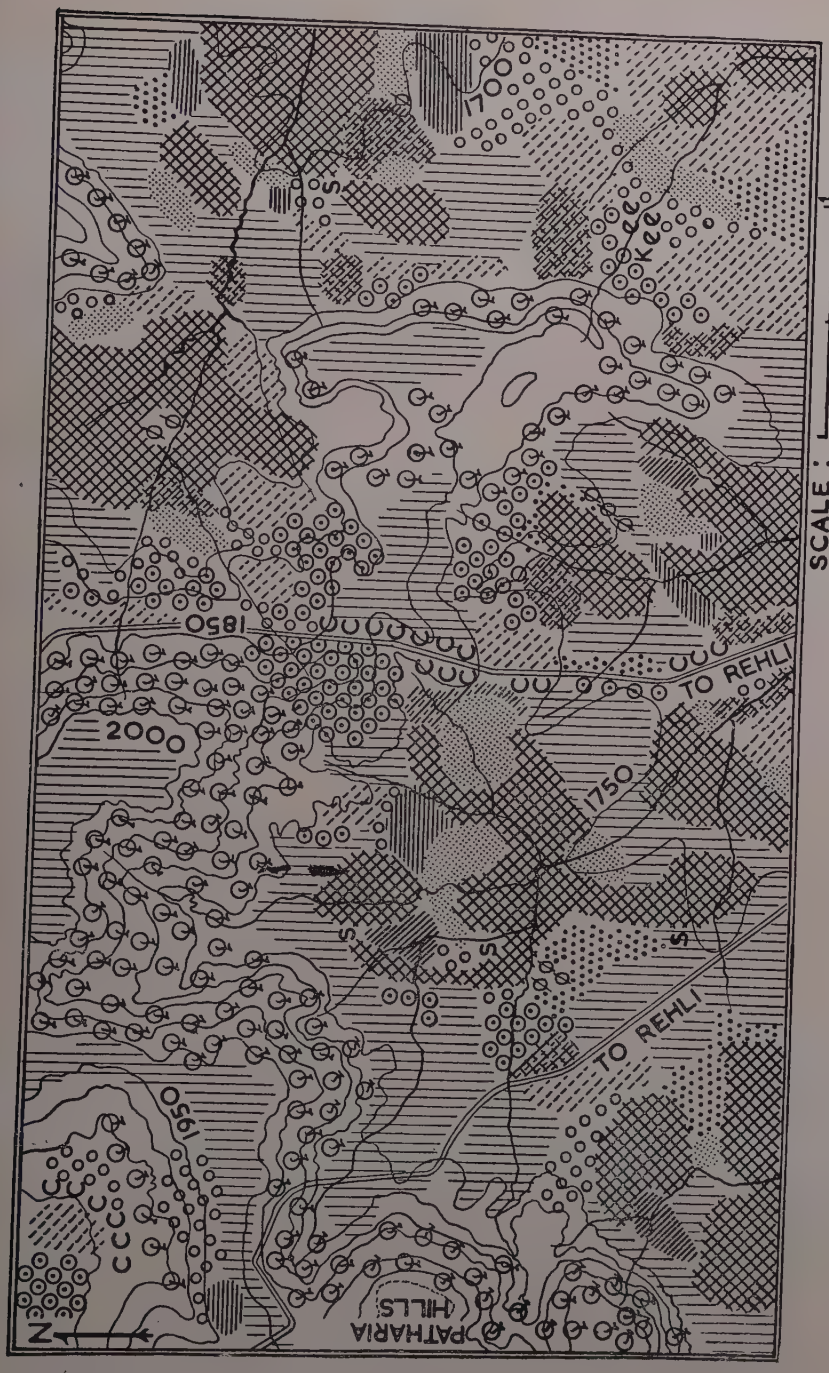
4. *Bothriochloa pertusa—Dichanthium annulatum* and *D. caricosum* association: under intense to moderate grazing; growing in thicker soil on uplands and lowlands.

5. *Heteropogon contortus* and *Andropogon pumilus* association: under intense to moderate grazing; growing in thin and coarse soils with underlying loose parent rock on uplands and slopes.

GRASSLAND MAP OF

Suburb Area To The East Of Sagar, Madhya Pradesh

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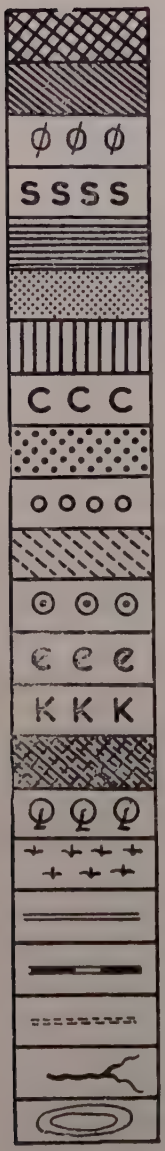
MAP – 1

INDEX



THEMEDA QUADRIVALVIS ASSOCIATION

DO. WITH *ISEILEMA ANTHEPHOROIDES* AS CO-DOMINANT

DO. WITH *OPHIUROS EXALTATUS* AS CO-DOMINANT

DO. WITH *SACCHARUM SPONTANEUM* AS CO-DOMINANT

CYMBOPOGON MARTINI & EULALIA TRISPICATA ASSOCIATION

DO. *E. TRISPICATA* DOMINATING

BOTHRIOCHLOA PERTUSA - DICHANTHIUM ANNULATUM - D. CARICOSUM ASSOCIATION

DO. WITH *CHLORIS VIRGATA* AS CO-DOMINANT

DO. WITH *DICHANTHIUM CARICOSUM* DOMINATING

HETEROPOGON CONTORTUS ASSOCIATION

DO WITH *ANDROPOGON PUMILUS* AS CO-DOMINANT

ARISTIDA DEPRESSA - A. CYANANTHA & MELANOCENCHRUS CENCROIDES ASSOCIATION

ERAGROSTIS TENELLA VARIENT

KYLLINGA TRICEPS VARIENT

SEHIMA NERVOSUM-CHRYSOPOGON FULVUS & TRIPOGON LISBOAE

UNDER FOREST GROWTH

MARSH LANDS

ROADS

RAILWAY LINE

'KACHHA' ROAD AND FOOTPATH

STREAMS AND 'NALAS'

CONTOURS: MINIMUM—1,725 ft.—527 12 METRES
MAXIMUM—2,050 ft.—625·20 METRES

6. *Aristida depressa—A. cyanatha* and *Melanocenchrus cenchroides* association: under intense to moderate grazing; growing mostly on very thin sandy soil on less withered parent rock on any topographic situation but mostly on uplands and gradual slopes.

7. *Coix gigantea* and *Ischaemum rugosum* association: kept fenced; soil underneath is very moist and thick; found in lowlands.

8. *Cynodon dactylon—Bothriochloa pertusa* and *Dichanthium* sp. association: under intense grazing in moist areas in all topographic situations.

Having distinguished the associations the next step was to show their existing pattern of distribution on a contour map of the area. Gaussen (1957) has given the scientific and economic value of such vegetational maps.

Method of Preparation of the Map

The grassland map of the area was prepared in the field during the months of September/October, 1950–51. First the whole area was divided into 10 compartments on the map. Next, each compartment was surveyed in detail and the associations were charted to scale on the contour map. All the compartments were then compiled into one vegetational map of the area. Areas under crop fields have been shown under such grassland associations as are surrounding them. Such areas occur only in lowlands and are not too many.

In spite of great care taken in exactly noting the area under a particular association, too much of reliance cannot be placed upon the exactness of boundary lines shown in the map. The map has been mainly drawn to have an approximate idea of the extent of distribution of various associations.

The grassland map of the area is presented in Map 1.

Detailed phytosociological characters of the associations shown in the map will be given in the second paper of this series.

Summary

1. An attempt has been made to present an ecological monograph of the grasslands lying in the suburb to the east of Sagar (Madhya Pradesh). The work comprises detail studies of the analytic and synthetic characters of the grasslands and environmental factors operating upon them. It is proposed to present this phytosociological monograph in 3 parts:—

Part I—Grassland map of the area on physiognomic basis.

Part II—Composition of the grassland associations.

Part III—Edaphic factors in the distribution of the associations.

2. In the forest climate of Sagar, grasslands have come upon removal of forests and are so maintained due to anthropogenic factors. Grasslands occur during monsoon period. Hay plots are harvested in October month and the grazed lands continue their growth till winters when most of the plants dry.

3. Situation, topography and climate of the area have been given.

4. The present paper being first in the series presents a grassland map of the area showing the existing distribution of grassland associations. Eight main associations have been recognised.

5. The investigations are first of the type in India.

Acknowledgements

I owe special gratitude to my teacher Prof. R. Misra, Head of the Department of Botany, Banaras Hindu University, for the painstaking guidance, valuable criticism and suggestions throughout the course of this study. My thanks are also due to the Government of India, Ministry of Education, for the award of research fellowship during the period of present investigations.

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LIFE-HISTORY OF *CYCAS CIRCINALIS* L.

Part I. Microsporogenesis, Male and Female Gametophytes and Spermatogenesis

By L. N. Rao

"Jaya Nivas", Gavipuram Extension, Bangalore-19

(Received for publication on August 5, 1961)

Of the five eastern genera of Cycadales, *Cycas* is the most prominent both in the number of species and in distribution of its sixteen species ranging from Japan to Australia. Three species—*Cycas circinalis* Linn., *C. pectinata* Griff. and *C. beddomei* Dyer—occur in India in wild state (Brandis, 1921). *Cycas circinalis* has been observed in wild state by the author at Melkote, Bannerghatta, Talaghatpur near Bangalore in Mysore State, near Chinglepet in Madras State and at Tenmalai, Kerala State. It is also grown in the gardens for its lovely crown of foliage of dark green pinnately compound leaves. The stem is columnar with the characteristic armour of leaf-bases. From the leaf-bases, the average number of leaves in a crown and the duration of the crown, the age of the plant can be determined (Chamberlain, 1935). The armour may not be persistent in the wild forms at least in the lower portion of the stem which is usually damaged by the grazing animals. Hence the stem remains smooth and white. The plant sometimes grows to a height of 10–15′ and exhibits zonations in the armour-foliage leaf-bases alternating with those of scale-leaves which also gives a clue as to the probable age of the plant (Pl. XVII, Fig. 2).

Formation of buds on the older trunks and near about the wounds on younger stems is a common feature. If the terminal growing point is damaged by any chance then a number of vegetative buds take their origin on the stem and grow. In *Cycas revoluta*, also a garden favourite, vegetative buds are formed even underground. They are formed only on the subterranean portion of the stem and never on the root.

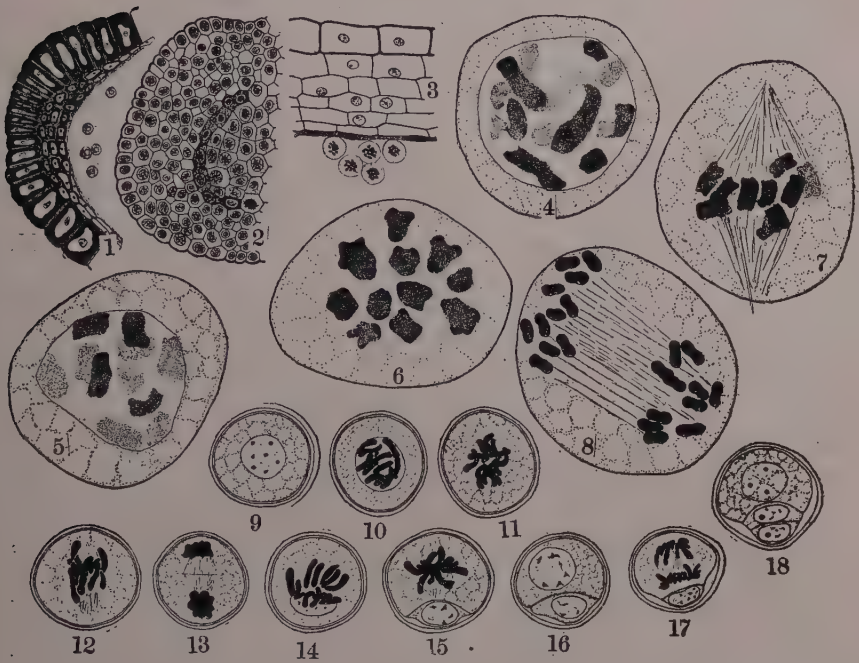
Material for this work was collected both from plants under cultivation and wild state. The collection of material began in 1922 at the suggestion of late Prof. Sampathkumaran who had first-hand working experience and knowledge of Cycadales with late Prof. C. J. Chamberlain of Chicago University. Plants under natural condition produce very few ovules and they could not be relied upon for sus-

The printing of the large number of Plates and Text-Figures has been possible by a generous subvention from the author.—*ED.*

tained work. Hence artificial pollination of female plants at proper times was tried and it was found very useful for a regular systematic work and collection. Male cones mature by the end of September and October in Bangalore. One of the male plants grown out of seeds sown in 1925 has produced a cone for the first time in August 1944. Young ovules appear in the female cones by about the same time. Female plants produce a large number of ovules under artificial pollination (Pl. XVII, Figs. 1 and 2; Pl XVIII, Figs. 4 and 5). Pollen tube takes about six months to develop and discharge the sperms and they are ready for collection usually in May or June of next year. On 22nd May 1924 the author was lucky to demonstrate for the first time to a class of B.Sc. students the movement of the swimming sperms of *Cycas circinalis* spinning majestically in a drop of water. That was a remarkable experience. Materials thus collected over a long period of time were passed on to me to be worked out. I am now putting together all the facts collected in the field and the material worked out in the laboratory in a connected form to give a general account of the life-history of *Cycas circinalis*.

There are very few works on *Cycas* specially *C. circinalis*. The earliest work is that of Treub (1884) on embryogeny of *Cycas circinalis*. Next is that of Ikeno (1898) and Ikeno and Hirase (1897) on *Cycas revoluta* and its spermatozoids. There is a long gap until Swamy (1948) gave an account of the life-history of a *Cycas* from Mysore during which period other genera of Cycadales have been worked out in the West especially in America. De Silva and Tambiah (1952) published the results of over four years' study on *Cycas rumphii* Miq. covering almost all the phases of the life-cycle in a general way. An attempt is made here to contribute to some of the stages that are still wanting in the life-cycle of *C. circinalis*. Microsporogenesis and development of the sperms have been studied in some detail. So also the fertilization and syngamy. The organization of the embryo has been studied to show that there is only one period of free nuclear division and not two, separated by a period of migration of the nuclei as in *Stangeria paradoxa* (Chamberlain, 1916).

Male Cone.—The plants are dioecious. There is no external indication to distinguish a male plant of *Cycas* from a female plant except at the time of reproduction. The male cone is very compact from the beginning and appears as a small body of the size of an apple when it emerges out of the scale-leaves covering. Its surface is covered over by brown scales, ramenta. As this cone grows and elongates it becomes bulky and begins to emit characteristic smell which can be detected even from a distance. The microsporophylls are arranged on a central axis in a spiral way and are so highly modified that they do not bear any resemblance to the foliage leaf. Few tooth-like structures at the terminal ends of the sporophylls betray their leafy nature. The microsporangia are found on the abaxial side of the sporophyll and are not spread over the whole surface. Further they are grouped in fours and fives to form a sort of synangia. Each sporangium has a massive but short stalk. Sporangial wall is five to six cells thick.



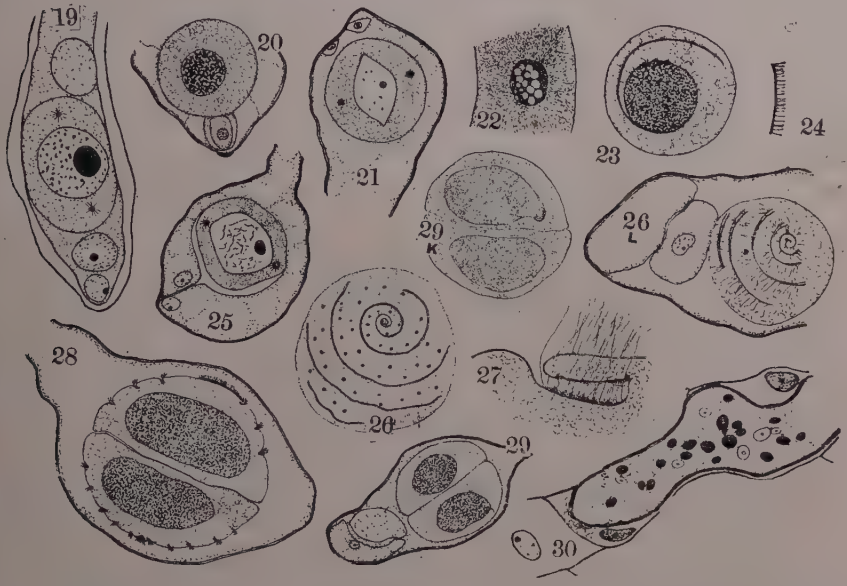
TEXT-FIGS. 1–18. Fig. 1. Terminal end of the microsporangium with the lignified epidermis and wall layers Smaller lignified cells mark the line of dehiscence, × 200. Fig. 2. Section of the microsporangium showing the separation of the tapetum from the sporogenous layers, × 350. Fig. 3. Part of the sporangium showing the wall layers, the spore mother cells and the disorganising tapetal layer between them, × 400. Figs. 4–8. Stages in meiosis, × 400. Figs. 6 and 7. Show two views of metaphase plates of bivalents. Fig. 8. Anaphase. Figs. 9–18. Early stages in the formation of the male gametophyte, × 1,800. Fig. 9. Microspore. Fig. 10. Prophase. Figs. 11 and 12. Metaphase of the first division. Fig. 13. Anaphase. Fig. 14. Prothallial nucleus is distinct. Figs. 15 and 16. The prothallial cell is separated by a wall and the generative nucleus divides—metaphase of the second division. Fig. 17. Anaphase of the second division. Fig. 18. Pollen at the time of shedding—prothallial, tube and generative cells are noticed. Magnification of the text-figures refer to the original figures which have been reduced in reproduction and hence to be read at half the value noted.

The wall cells at the anterior end are modified to form an annulus which indicates the position of dehiscence of the sporangium when ripe (Text-Fig. 1; Pl. XIX, Fig. 7). Sporogenous cells are hexagonal in section, thin-walled with rich contents. They are closely packed in sporangial cavity. After several divisions they give rise to spore mother cells with rich contents (Text-Fig. 3; Pl. XIX, Fig. 8). During this process a number of cells do not develop normally but lag behind and finally get disorganised. So there is some sterilization of potential sporogenous cells. The spore mother cells become rounded and appear to be free in the cavity of the sporangium. There is a layer of tapetum which is derived from the outermost layer of the sporogenous tissue. This fact has been proved by two evidences. The

wall layers are well differentiated long before the tapetum appears. The orientation of the cells of the tapetum is different from that of the wall cells (Text-Figs. 2 and 3). This type of the origin of tapetum is reported by Smith (1904) in *Zamia* and *Ceratozamia*. With the formation of the microspore mother cells the tapetum becomes depleted of its contents and begins to disorganise, leaving a mass of nucleated protoplasm. The spore mother cells undergo the usual reduction division and form the microspores. The reduction division occurs simultaneously in all the cells of the sporangia (Text-Figs. 4–8; Pl. XIX, Fig. 8). Meiotic divisions take place in quick succession. the nuclei resulting from the first division having very short period of rest. The spindle of the second division may be parallel or at right angles to each other (Pl. XIX, Fig. 10). The division of the microspore mother cell is by furrowing method. The exine is thicker than intine and remains smooth throughout. Eleven bivalents were counted in *C. circinalis* (Text-Figs. 6 and 7; Pl. XIX, Fig. 9) while 12 is the number reported for almost all the genera. Sharma and Chaudhuri (1960) report 12 chromosomes in *C. circinalis*. Smith (1904) reports 11 chromosomes in *Ceratozamia* as a rarity. Of these chromosomes 4 are longer than the rest. De Silva and Tambiah (1952) have shown in their Fig. 73, the number of chromosomes to be 11 in *C. rumphii*. When this paper was in the galley proof stage, B. V. Shetty and K. Subramanyam have determined and reported the diploid number of *Cycas circinalis*, *C. beddomei* and *C. revoluta* to be 22. (*Proc. Ind. Sci. Congr.*, 1962, Part III, p. 259). Microspores are arranged in a tetrahedral manner within the spore mother cell. They are freed by the rupture of the wall and come to lie in the cavity of the sporangium. After a period of three to four days the nucleus of the microspore divides to form two, followed by a wall formation. Thus two cells, the prothallial and the generative cells are formed (Text-Figs. 9–15). The generative cell divides again to form two cells—the tube cell and the body cell (Text-Figs. 16–18). Thus as a result of two mitoses three cells are formed which are still enclosed by the microspore wall. It is this body which is called the pollen and which is carried away by the wind and dispersed. It is not a microspore but a male gametophyte consisting of three cells that is dispersed by the wind (Text-Fig. 18; Pl. XIX, Fig. 11).

The wall layers of the sporangium undergo change. The epidermis becomes highly lignified. The annular cells as well as those along the line of dehiscence also become lignified. Almost all the wall layers would have collapsed leaving only traces beneath the annulus at the time of dehiscence. By now the axis of the male cone elongates rapidly thus providing plenty of room in between the sporophylls for the free play of wind. The pollen shed by the sporangia first collects on the dorsal surface of the lower sporophylls and finally carried away by the wind. *Cycas* is an anemophilous plant. Both the male and the female plants with their adaptive devices are best suited for wind pollination. Finally after the pollen is completely shed, the male cone loses its turgidity and collapses to a side (Pl. XVII, Fig. 3). A fresh

crown of leaves takes its origin from the terminal end of the stem, showing thereby that the male cone is not terminal in position.



TEXT-FIGS. 19–30. Fig. 19. The tip of the pollen tube with the prothallial, the stalk and the body cells; the prothallial cell is enlarging, × 800. Fig. 20. The tip of the pollen tube with the prothallial and the stalk cells abutting against the body cell, × 200. Fig. 21. Bulged tip of the pollen tube with the large body cell and the disorganising prothallial and stalk cells, × 200. Fig. 22. Part of the body cell showing the vacuolated blepharoplast, × 1,200. Fig. 23. Sperm cell with the elongating spiral band attached to the nucleus, × 300. Fig. 24. Part of the spiral band enlarged to show the formation of finger-like processes or "basal bodies" from which cilia arise, × 2,700. Fig. 25. The prothallial and the stalk cells have enlarged to envelop the body cell, × 200. Fig. 26. Sperm showing number of full coils of the spiral band. Dark-stained, regularly placed bodies give a peculiar appearance to the sperm, × 300. Fig. 26 *a*. Double edge of the spiral band can be seen clearly, × 400. Fig. 27. Part of the section of the sperm to show the portion of the spiral band and the cilia, × 2,700. Fig. 28. The body cell with the two sperm mother cells each with a well-organised sperm, × 300. Fig. 29. The body cell dividing to form the two sperm mother cells. Note the spiral band attached to one sperm nucleus, × 250. Fig. 29 *a*. Body cell dividing to form the sperm mother cells. Note the beak-like projection of one of the sperm nuclei, × 250. Fig. 30. Haustorial tip of the pollen tube showing the lamellated intine whose secretion has digestive action on the cells of the nucellar beak. Within the tube there are a number of starch grains and fat bodies, × 1,200. Magnification of the text-figures refer to the original figures which have been reduced in reproduction and hence to be read at half the value noted.

Pollination.—Pollen is carried away by the wind and remains suspended in the air for some time. During this period the pollen is likely to travel some distance before it finds a female cone to receive it. Young ovules of the female plant secrete a liquid which collects at the tip of the micropyle in the form of a drop which has been appropriately called "The Pollination Drop". This drop of liquid helps

in catching the air-borne pollen grains and conducting them by suction down to the pollen chamber (Pl. XVII, Fig. 2).

Pollen tube.—The pollen remains inactive in the pollen chamber for some time and then develops the pollen tube. The number of pollen tubes that develop in each ovule varies. Normally five to six tubes are met with. In one case as many as 12 tubes were counted while in others none at all (Pl. X X, Figs. 12 and 13). The first sign of the growth of pollen tube is its breaking through the exine. The intine comes out and through its secretion and its digestive action, it grows eating its ways as it were through the nucellar beak and finally emerges into the archegonial chamber. The distal end of the tube ramifies and sometimes branching in the tissue of the nucellar beak. It absorbs nutrition from the surrounding tissue and grows (Text-Fig. 30; Pl. X X, Fig. 13). With a magnifying glass it is a nice sight to see number of glistening swollen tips of the pollen tubes hanging down the roof of the archegonial chamber. The digested-material of the nucellar beak is left behind which takes a deeper stain and indicates clearly the course taken by the pollen tube. As the pollen tube grows, the three cells, the prothallial, the generative and the tube cell descend from the pollen grain and migrate into the tube and keep themselves always to the tip (Text-Figs. 19–21). Of the above three cells the first to divide is the generative cell. After it has attained its maximum size, it divides forming two cells one lying above the other. The upper one grows bigger and forms the body cell and the lower forms the stalk cell. In *Cycas revoluta*, however, Ikeno (1898) reports that the generative cell divides by a vertical division resulting in the formation of two parallel cells either of which might become the body cell. The stalk and the prothallial cells grow and enlarge so as to envelop sometimes the body cell from either sides (Text-Fig. 25). According to Chamberlain (1909) in *Dioon* the growth of the prothallial cell proceeds so far that it presses against the wall that separates the body cell from the stalk cell. In *Cycas circinalis* the enlarged stalk cell and the prothallial cell often bulge out so much that they appear to be twisted one over the other.

Spermatogenesis.—The body cell grows and enlarges to become easily the biggest cell of the pollen tube complement. No metaplastic bodies are found in it. When it is amidst the tissue of the nucellar beak the body cell will be longer than broad (Text-Fig. 19), the long axis being parallel to that of the pollen tube. But later when the pollen tube emerges into the archegonial chamber and enlarges, the body cell also becomes spherical being perhaps released from the pressure of the adjacent tissue (Text-Fig. 21; Pl. X X, Fig. 15). Very soon a bright spherical shining body almost looking like a nucleolus appears in the cell. This body gradually develops out of the cytoplasm with a number of radiating strands similiar to that of centrosomes or "Asters" of animal cells. Blepharoplast, as this body is called, soon divides to form two blepharoplasts each with its radiating cytoplasmic strands (Pl. X X, Fig. 14). They gradually move apart and take up a

parallel position to begin with (Text-Fig. 19). Later, on the way to the archegonial chamber, they move through an angle of 90 degrees and take up a position at right angles to the long axis of the pollen tube. They persist in that position even during the preparatory stages of the division of the body cell (Pl. XIX. Fig. 15). The first sign of such preparation is the change in the shape of the nucleus. The spherical nucleus assumes a broad spindle shape (Pl. XIX, Fig. 16). The nucleolus disappears. Even at this stage the two blepharoplasts are situated at right angles to the long axis of the mitotic spindle (Pl. XIX, Fig. 15). Just before the division of the body cell the blepharoplasts become ovoid in shape. Vacuoles appear in its body reducing it ultimately to a mass of granules (Text-Fig. 22). The fact that the body cell divides first and is followed by the breaking up of the blepharoplasts is supported by Chamberlain (1935) and Brough and Taylor (1940). In *Microcycas* according to Caldwell (1907) and in *Dioon* according to Chamberlain (1909) the two processes appear to take place more or less simultaneously, while in Stangeria, Chamberlain (1916) the activity of the blepharoplasts starts earlier. By now the nucleus of the body cell has divided into two, each of them lodged in a sperm mother cell formed by the division of the body cell (Text-Figs. 29 and 29 *a*; Pl. XX, Figs. 21 and 24). The sperm mother cells are hemispherical in shape and will be bound partly by the body cell-wall and partly by the newly formed partition wall. Sperms are organised by these mother cells at the rate of one per mother cell. Some time later, the spiral band with numerous cilia are organised in each to take its final position. Each spiral band forms five to six turns and ends at the apex of the top-shaped sperm (Text-Figs. 26 and 28; Pl. XX, Figs. 23–25). Though some structural details of the spiral band has been made out in the available material, the exact way the band is originated could not be made out. At any rate no convincing direct evidence could be traced though in other genera blepharoplasts are credited to have given rise to them. Chamberlain (1909) has worked out the origin of the spiral band from the blepharoplast in *Dioon*. He has detected the presence of grey and black bodies in the cytoplasm of the body cell which are supposed to have come out of the nucleus either bodily or in a dissolved state. The blepharoplast which appears later in the centre of the radiating grey and black bodies is described as being fed and developed by them. The development of the blepharoplasts in *Microcycas* has been given by Downie (1928). The vacuolated plate of the blepharoplast breaks off into a number of pieces in the cytoplasm which elongate and produce cilia. In *Cycas circinalis*, however, in certain preparations the grey particles are found arranged in a radiating manner from the blepharoplast. Since the appearance of the blepharoplasts is rather sudden, their growth even in the absence of grey and black bodies leaves one to doubt whether their origin has anything to do with the grey and black bodies at all. The origin of the spiral band from the blepharoplast could not be traced in a convincing manner. Yet its first appearance as arcs of circles situated round the nuclei of the sperm mother cell can be made out (Text-Fig. 23; Pl. XIX, Fig. 17). These arcs appear to elongate,

join together end to end and finally winds itself round the nucleus in a spiral manner with one end attached to it (Pl. XIX, Fig. 17; Pl. XX, Figs. 20 and 21). Then this spiral band migrates gradually towards the periphery of the sperm cell, leaving the nucleus in the centre. As it migrates, it undergoes certain changes. The band becomes thick, flat and ribbon-like (Text-Figs. 26 *a* and 27; Pl. XX, Fig. 22) one end of which remains embedded in the cytoplasm while the other develops cilia all its length. Along the outer margin of the spiral band large number of finger-like processes make their appearance. It is these processes (Text-Fig. 24; Pl. XIX, Figs. 18 and 19; Pl. XX, Fig. 20) or the basal bodies that ultimately produce the fine cilia. This observation has been supported by Sharp (1934) who says that students of spermatozoid development have described the cilia as growing out of the chromatic thread (Blepharoplast); though recent observers of mature spermatozoids report that they appear to be attached to the basal bodies in the cytoplasmic band whose margin is formed by the thread (Border Brim). This can be noticed clearly in sections of sperms (Text-Fig. 28; Pl. XX, Figs. 25 and 26). Five to six turns of the spiral band can be noticed (Text-Figs. 26 and 28; Pl. XX, Figs. 23–25). In some cases 6–8 turns are observed. It is always a right-handed coil as seen from the apex of the sperm. Each sperm which is top-shaped performs a wonderful spinning movement. It spins on its broader base unlike the top which it resembles. Just before their release from the sperm mother cell, the measurement of the sperms will show the following features: The average breadth is 162 μ ranging from 120–189 μ. The average height, that is from the apex to the base, is 78 μ ranging from 72–87 μ. The nucleus of the sperm forms its major bulk, the thickness of the cytoplasm on an average being 12 μ at its thinner parts and 42 μ at the thickest part. The length of the sperm nucleus as seen in vertical section ranges from 84–90 μ. The coils of the spiral band are spaced at a distance of 3 μ, 6 μ, 18 μ and 27 μ from the apex measured along the radius (Pl. XX, Figs. 23 and 25).

In *Cycas circinalis*, the body cell divides into two sperm mother cells and each of them gives rise to a sperm. The partition wall separating the two sperm mother cells arises afresh while the sides are parts of the old body cell-wall (Text-Fig. 29; Pl. XX, Fig. 21).

Female strobilus or cone.—The female cone though appears to be terminal in position is not really terminal. The cone arises in August or September in Bangalore and will be covered over firmly by the scale-leaves forming a terminal dome of the size of an orange. As the dome grows in size, it forces its way separating the scaly leaves. By now the crown of functioning foliage leaves changes its position, *i.e.*, the leaves try to change their position as if to make room for or exhibit the female cone (Pl. XVII, Figs. 1 and 2). The cone is made up of a large number of megasporophylls arranged spirally on a short axis. Naturally the young sporophylls are at the apex and the older ones at the base of the axis. The sporophylls are covered over

by brown-coloured hairs from the beginning and are divisible into two distinct parts—the stalk which is roughly cylindrical, gradually expands into the ovule bearing sporophyll proper (Pl. XVIII, Fig. 4). The terminal end of the sporophyll is broad with dentate margin and ends in a pointed tip. In order to be accommodated in the compact cone each sporophyll will adjust its length, the outer one being longer and the central ones being shorter. Further they will be subjected to extra pressure in the cone from the growing adjacent sporophylls whose impressions they carry even at a later stage. Each sporophyll bears along its two margins or edges a number of ovules, their number ranges from one to twelve per sporophyll (Pl. XVIII, Fig. 6). All these might develop into functioning ovules or some of them or even all of them might end as abortive ovules and remain attached to the sporophyll as dried up vestiges. With the growth of the ovules the sporophylls till now compactly packed in the cone grow and elongate and thus the cone becomes loose (Pl. XVIII, Figs. 4 and 5). The sporophylls becoming spread out, a new crown of foliage begins to emerge from the terminal end of the stem thus helping the sporophylls to spread out further. The new young crown of leaves will be vertical in position, *i.e.*, stand erect from the stem apex and gradually assume an angle of 40° to the vertical by the time the leaves become fully grown with dark green colour. Two sets of foliage leaves can be noticed on the tree at this time and between them a set of scale-leaves and a set of megasporophylls forming the female cone (Pl. XVII, Fig. 1). It is rare to come across the above condition with the full complements. One set or the other will be missing usually due to the action of various destructive agents including man.

Megasporangium.—Since the young cone is situated below the level of the stem apex it has been found difficult to cut the stem apex without damaging it to secure the early stages of the megasporangium and its developing stages. Even if the stem tip is cut at the cost of its life, one is not certain about what is growing beneath the tip. It may be an young cone required or an young bud of foliage not required for the purpose. The young sporangium or the ovule of the size of a small pea has a massive integument which has not been differentiated into layers. This integument encloses the nucellus in which two regions can be seen, the upper pointed dome-shaped beak which projects into the micropyle and through which communicates with the exterior and the lower spherical belly. The nucellar beak is free from the integument, the space between being the future pollen chamber (Text-Fig. 31; Pl. XX, Fig. 27), while the belly is in contact with the cells of the integument. Further we see in the middle of the beak cells becoming rounded and breaking down to form the extension of the pollen chamber where the nucellar beak cells are exposed to receive the pollen grains. The surface of the beak all round is lined by tannin containing cells, which become brown with Haematoxylin stain. In the lower portion of the nucellus the megaspore develops. In the earliest stage studied, the megaspore was in the free-nuclear stage, *i.e.*, it had already become a gametophyte (Pl. XX, Figs. 27 and 28).

All round the growing gametophyte, 5–6 layers of cells of the nucellus are organized to form the "nutritive jacket" whose function appears to be to feed and supply nutrition to the gametophyte. The cells of the nutritive jacket are large, very rich in cytoplasm in which are embedded big nuclei nearly half the diameter of the cell. In some cells two large nuclei can be noticed without even any sign of a partition wall (Pl. XXI, Figs. 32 and 33). External to this jacket, forming part of it, there are two or three layers of cells which are flattened with small nuclei. These layers form the boundary line between the "endosperm jacket" and the nucellus. Further, as the gametophyte or the endosperm grows, the cells of the inner layers of the nutritive jacket become depleted of their contents, become flat and remain as black bodies. The same fate follows the other cells also. By the time the integument is differentiated into two layers, the nutritive jacket disappears completely or only its remnants remain. There does not appear to be any reference to this nutritive mechanism of *Cycas* in the previous works. However, De Silva and Tambiah (1952) have stated that in *Cycas rumphii* the nucellus at this stage, *i.e.*, free-nucleate megaspore, shows two regions, a central region surrounding the developing female gametophyte and composed of small radially arranged cells containing densely staining cytoplasm which is probably tapetal in nature and rapidly disappears as the megaspore enlarges. Endosperm jacket has been described in *Microcycas* by Reynolds (1924) where out of the four layers of cells, two are differentiated into thick, plump cells immediately surrounding the gametophyte and a layer outside it of flattened cells fitting loosely together.

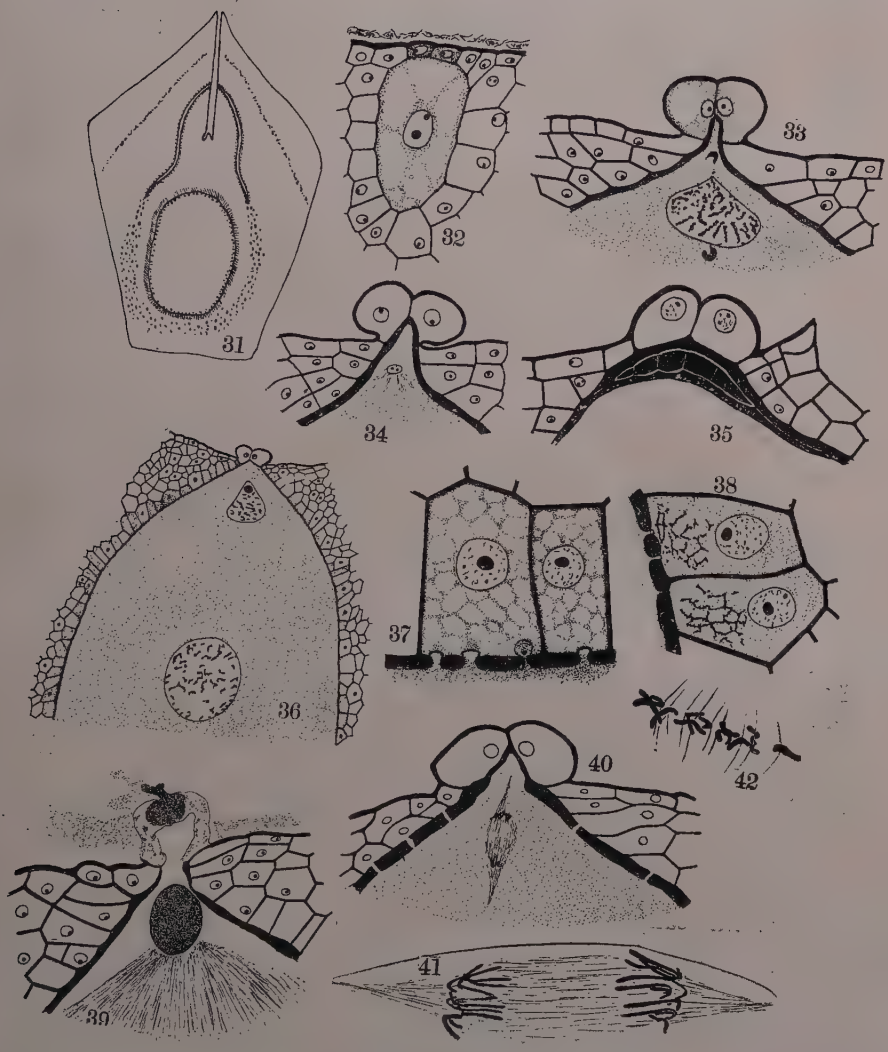
The central column of cells of the nucellar beak breaks down to form the extension of the pollen chamber and extends half way down the dome of the nucellar beak. The female gametophyte enlarges, its nuclei divide to form a large number by free nuclear division and spread themselves uniformly all round the cytoplasm. Due to disparity in the rate of growth of the gametophyte and its protoplasmic contents, a vacuole appears in the centre which becomes bigger and bigger and pushes the cytoplasm and the nuclei to the periphery. Number of small vacuoles might also appear which unite to form a big one finally. Plate XXI, Figs. 32 and 33 shows a thick layer of cytoplasm surrounding the central vacuole and the free nuclei embedded in it.

Just at this stage of development of the female gametophyte, the differentiation of the integument begins. At the micropylar region the middle zone which is to become the future stony layer or seedcoat appears. The cells of this zone are elongated with dense cytoplasmic contents. Few scalariform tracheids are also formed. The part of the integument external to this zone forms the outer seedcoat or the outer fleshy layer or coat, while the inner part gives rise to the inner soft layer or coat. These are the three seedcoats of which the outer one develops tannin cells and mucilage ducts which play an important part in the seed dispersal and seed protection in early stages.

The megaspore membrane, which is partly broken up into pieces by now, still adheres to the gametophyte and is about 2–3 μ thick. The cells of the nutritive jacket or the endosperm jacket have partly broken down, leaving a gap between themselves and the gametophyte. As the gametophyte enlarges the cytoplasmic layer becomes thin and the nuclei are uniformly spaced along the periphery of the gametophyte. Wall formation begins (Pl. XXI, Fig. 33). Some of the cells of the nutritive jacket adjoining the megaspore membrane can be seen to have exhausted themselves leaving behind only a black mass while others are still healthy with rich contents. The megaspore membrane at this stage is about 3–4 μ thick though continuous for long distances. With the formation of the peripheral layer of cells in the gametophyte, further growth begins. The cells divide periclinally to begin with and thus several layers of cells are formed which encroach upon the central vacuole. The central vacuole itself at this stage is filled with a clear sweet liquid like the milk of the coconut. Further growth of the endosperm cells completely fills the vacuole, fully utilizing the liquid contained in it. By now the megaspore membrane has been so much stretched out that it becomes broken up into thin pieces. The cells of the endosperm at the periphery are crowded, while at the centre as well as at the lower end (opposite the micropylar end) of the gametophyte they are loosely packed. Further, the cells at the micropylar end are smaller in size, rich in contents and with proportionately bigger nuclei. These are certainly the signs of great activity which consists of not only the formation of an archegonial chamber but also the formation of archegonial initials. According to Chamberlain (1935) the endosperm cells all round the region where the archegonial initials are to be formed, grow and lead to the formation of a shallow pit. This pit is called the "archegonial chamber". At the bottom of this pit, as it were, the archegonial initials appear. The archegonial chamber is bounded above by the megaspore membrane, the remnants of the nutritive jacket and the overlying nucellar beak tissue. By the time the archegonia become mature, the above super-laying structures disorganise leaving a free passage leading down from the pollen chamber to the archegonial chamber. It is into this space the pollen tube or male gametophyte projects and when mature, discharges its contents.

Archegonium.—One of the superficial cells at the micropylar end of the female gametophyte becomes bigger than the surrounding cells with rich cytoplasm and a large nucleus. This cell becomes the initial of an archegonium. One to seven such initials are observed in an ovule. The initial cell divides periclinally giving rise to an outer neck cell and the inner central cell. The neck cell divides anticlinally and forms two neck cells which do not divide further and remain at the level of the surrounding cells. The central cell grows bigger and bigger and its nucleus remains all along near to the neck cells. This is the full complement of the *Cycas* archegonium (Pl. XXI, Figs. 34–36). On account of the differential growth of the central cell and its cytoplasm, number of vacuoles appear which may fuse to form large ones. Simultaneously with the growth of the central cell, the surrounding

cells of the gametophyte organize a jacket layer—Archegonial Jacket —made up of one layer of cells arranged in a pavement-like manner. As the central cell approaches full size, it receives various food substances from the surrounding tissue. This accumulation of reserve material in the central cell is called the "nutrition of the egg" (Text-Fig. 32; Pl. XXI, Figs. 34, 36 and 39). While the central cell is enlarging, its wall undergoes complete change by the accumulation and incorporation of chemical substances like pectin and amyloid substances besides the original cellulose. The wall also becomes pitted (Text-Figs. 37 and 38; Pl. XXI, Figs. 40 and 41). This is the egg membrane, through which the food materials from the surrounding tissue enter the central cell. As regards the transfer of materials from the neighbouring cells to the central cell, there are different views expressed by previous workers on Cycads, and these views have been summarised by Coulter and Chamberlain (1910). So far as *Cycas circinalis* is concerned, the relation between the huge egg cell and its neighbouring jacket cells is exactly like the one found in *Zamia floridana* by Isabel Smith (1904) and in *Dioon edule* by Chamberlain (1909). The central cell-wall which becomes ultimately the egg membrane is very thin to begin with. It is a mistake to call the central cell the egg cell at this stage. However, for the sake of brevity, we may call it as an egg cell or mere egg. As the egg enlarges its cell-wall becomes gradually extended and thus it has to get itself reinforced by the addition of new layers. During the process number of pits are formed in the wall. Through these pits, the egg cytoplasm extends into the adjacent jacket cells and expands to form cushion-like bodies. The middle lamella is disorganized to facilitate the extension of the cytoplasmic processes (Text-Fig. 37; Pl. XXI, Figs. 40 and 41). According to Swamy (1948) after the jacket layer has become depleted of its contents, the pores between the central cell and the jacket cells become occluded by the formation of plug-like thickenings. Evidently the cytoplasmic expansions of the egg into the jacket cells—haustoria—have been mistaken for the plug-like thickening. Further, the plug-like thickenings are formed even when the jacket cells are full of nutritive materials, rich cytoplasm and nucleus, showing thereby that they are not formed for plugging away the jacket cells from the egg but for facilitating the flow of materials. Haustorial expansions inside the jacket cells will only increase the area of absorption, since the bodily movement of food materials from the jacket cells to the egg is not possible. Further, that the haustorial processes of the egg are not mere plugs formed to seal off the pores but are the real extensions and expansions of the egg cytoplasm inside the jacket cell is proved beyond doubt by a careful examination of a micro-preparation where the egg cytoplasm has receded or contracted from the egg membrane. One can observe that the margin or the outer boundary of the receded egg cytoplasm is not smooth but is dotted by a number of projections. Each one of these projections is a haustorial process coming out or rather being pulled out of the pore or pit by the contracting cytoplasm (Pl. XXI, Fig. 40) and those that are not pulled out but become wedged in the pores appear like plugs. This feature has been described by Treub (1884;



TEXT-FIGS. 31–42. Fig. 31. Section of the young ovule with the micropyle leading up to the centre of the nucellar beak, pollen chamber, the "nutritive jacket" and the central female gametophyte in the formation, × 70. Fig. 32. Young archegonium with two neck cells and a central cell; the thick line is the megaspore membrane, and above it are seen the remnants of the nucellar cells, × 400. Fig. 33. The upper part of the archegonium showing the ventral canal nucleus with extruded chromatin. Neck cells are intact, × 400. Fig. 34. Top of the egg cell with the ventral canal nucleus disorganising. Note the striations in cytoplasm just beginning, × 30. Fig. 35. The neck of the archegonium occuluded with dark staining material, a good indication of the presence of a fertilised egg, × 400. Fig. 36. An archegonium with its jacket, two neck cells, a ventral canal nucleus and an egg nucleus, × 100. Fig. 37. Egg cytoplasm forming haustoria which

enter the jacket cells through the pores or pits, × 900. Fig. 38. Contents of the jacket cells depleted. Dark staining bodies found, × 900. Fig. 39. The upper part of the archegonium with the collapsed neck cells, pollen tube fluid and the sperm which has got into the archegonium. Striations in the cytoplasm are more prominent, × 300. Fig 40. Upper part of the archegonium, with the division of the central nucleus to form the ventral canal nucleus and the egg nucleus. Egg membrane has developed pits; it is thicker than before, × 400. Fig. 41. Anaphase in the division of the central cell nucleus enlarged, × 1,800. Fig. 42. Metaphase in the division of the central nucleus showing eleven haploids, × 1,800. Magnification of the text-figures refer to the original figures which have been reduced in reproduction and hence to be read at half the value noted.

Pl. XIX, Figs. 7–10) where the contracted cytoplasm exhibits the haustoria clearly. Some haustoria, even after they are pulled out of the pores, appear to increase in size and remain for a long time as wart-like growth on the surface of the egg cytoplasm (Pl. XXI, Fig. 38). Having the above mechanism, the egg cell or the central cell receives and accumulates a huge quantity of reserve materials. The egg of Cycads, when fully developed, is very big reaching a length of about 6 mm., with breadth of about 2 mm.

While these changes are going on in the central cell, its nucleus undergoes a division very near its apex or the micropylar end. We may also call this as the neck region of the archegonium. Considering the difficulty in obtaining the division of the central cell nucleus into ventral canal nucleus and the egg nucleus, it is presumed to take place very rapidly. However, in *Cycas circinalis* the division figure compared with the huge mass of cytoplasm and the reserve materials appears to be very small (Pl. XXI, Fig. 37). Its small and microscopic size against the expectation makes one doubt whether it is the nucleus of the central cell at all that is dividing (Text-Figs. 40–42; Pl. XX, Figs. 29–31). The two small nuclei thus formed move apart, the lower one to the centre of the central cell now unmistakably called the egg nucleus or mere egg, while the upper—the ventral canal nucleus—to the apical end of the egg cytoplasm, finally to be disorganized and pushed out of the cytoplasm (Text-Fig. 36; Pl. XX, Figs. 30 and 31). The ventral canal nucleus is roughly pyramidal in shape and hence looks triangular in section, with the apex directed towards the neck of the archegonium. Dark bodies taking deep stain with Haematoxylin are found associated with the nucleus. It is doubted whether they are extruded by the nucleus (Text-Fig. 33). Radiating cytoplasmic lines are visible from the ventral canal nucleus, which persist for some time even after the disappearance of the ventral canal nucleus. These radiating striations are mistaken as the preparation by the egg for the reception of the sperm. Such striations are not found in every preparation showing the entry of the sperm, but invariably found in varying degrees in all cases of ventral canal nuclear outward journey (Text-Figs. 34 and 39).

The egg nucleus during its downward journey enlarges so much that it becomes in some cases fifteen to twenty times the size of the central cell nucleus. In the early stages the nucleus stains to the same

degree as the surrounding cytoplasm of the egg cell. But gradually, the staining capacity of the nucleus increases probably due to inclusion of more chromatin bodies. Sedgwick (1924) has observed similar rapid increase in size of the egg nucleus in *Encephalartos villosus* which he attributes to the inclusion of mass of cytoplasm. In *Cycas circinalis*, the fine granular structure of the egg nucleus and its uniform distribution throughout the nuclear cavity leaves no doubt that the entire nucleus is made up of chromatin material, its contents and distribution change with the stages of growth or division, thus changing the staining capacity of the nucleus. When the nucleus of the egg is ready to receive the sperm nucleus, the surrounding cytoplasm forms in some cases a halo all round the egg nucleus, where the cytoplasm appears to be almost colourless and thin (Pl. XXI, Figs. 42 and 43). No radiating fibres or threads are noticed. Nuclear membrane becomes very clear now being projected against the halo.

By this time the two chambers already mentioned, the pollen chamber and the archegonial chamber, become one continuous cavity by the disorganisation of the intervening tissues. The tip of the pollen tubes or male gametophyte discharge their contents into the archegonial chamber.

After fertilisation, the neck of the archegonium will be closed by a dark staining material (Text-Fig. 35).

Summary

1. *Cycas circinalis* L. growing wild as well as under cultivation was studied with regard to its habit and relation to the edaphic factors.

2. Artificial pollination gave excellent results and this method has been found very useful in securing a regular supply of material for a chronological study of the life-history.

3. The structure of the staminate cone, microsporangium and its development are given. Microsporogenesis and the spermatogenesis have been studied in detail. Chromosome number has been determined for the species.

4. The structure of the ovulate cone, megasporophyll with megasporangia have been described. The development of the female gametophyte, the presence and functions of the 'Endosperm Jacket' have been dealt with in full. The formation of the pollen chamber and the entry of the pollen into it is given.

5. The origin and the development of the archegonium, the division of the neck cell, the division of the central cell into the ventral canal nucleus and the egg nucleus and their ultimate fate have been described.

6. Formation of the archegonial jacket, the haustoria, their nature, longevity and the nutritive mechanism of the egg have been studied and described.

7. The formation of the archegonial chamber, the final position where the pollen chamber communicates with the archegonial chamber, the entry of the pollen tubes into the archegonial chamber, the disorganisation of the endosperm jacket cells and the megaspore wall immediately above the archegonial chamber have been studied.

Acknowledgement

The author wishes to thank Prof. Dr. M. K. Subramaniam, Department of Fermentation Technology, Indian Institute of Science, for the photomicrographs Pl. XIX, Fig. 9 and Pl. XX, Fig. 29 and Smt. K. S. Nalini (Mrs. L. S. Rao) for preparing the manuscript ready for the Press.

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Explanation of Plates XVII–XXI

Plate XVII

Figs. 1–3

Fig. 1. Ovulate plant of *Cycas circinalis* showing the two sets of foliage leaves and the ovulate cone between them. The large number of ovules are produced as a result of artificial pollination.

Fig. 2. Another ovulate plant showing the ovulate cone with young ovules. Note the armour of leaf-bases forming rings round the cylindrical trunk. The sporophylls are compactly packed, only the ovules peeping out. Below the cone are the whorls of scale-leaves, foliage leaves and dried up sporophylls of previous season.

Fig. 3. A staminate plant of *Cycas circinalis* with two cones, one on the left is at the pollen shedding stage with the collected pollen mass on the dorsal side of the sporophylls while the one on the right has already collapsed.

Plate XVIII

Figs. 4–6

Fig. 4. Close up view of the cone in Pl. XVII, Fig. 1, before the appearance of the upper set of foliage leaves. Note the number of ovules and the tips of the megasporophylls with dentate margin.

Fig. 5. Ovulate cone of another plant shown in Pl. XVII, Fig. 2, at a late stage of development. Note the central vegetative bud covered by scale-leaves.

Fig. 6. Megasporophylls bearing from one to twelve ovules.

Plate XIX

Figs. 7–19

Fig. 7. Transverse section of a portion of the microsporangium, showing the wall layers, annulus, tapetum and the sporogenous tissue, × 170.

Fig. 8. First division of the meiosis. Note the spindle and the partition wall extending to the border and beyond the mother cell to form the phragmoplast, × 300.

Fig. 9. Eleven bivalents are seen and counted, × 1,030.

Fig. 10. Tetrads enclosed in mucilagenous matrix out of which the microspores slip out when mounted in water. The matrix is derived probably from the phragmoplasts, × 80.

Fig. 11. Germination of the microspores to form the two- and three-nucleate bodies, *i.e.*, the male gametophyte, × 300.

Fig. 12. Portion of the nucellar beak with number of pollen tubes invading it. At least seven tubes are there as determined by the number of body cells in the picture, × 50.

Fig. 13. Nucellar beak with the haustorial end of the pollen tubes ramifying its tissue, while the basal portions are in the pollen chamber. In one of the tubes, the body cell nucleus is in the division stage, × 50.

Fig. 14. Portion of the body cell showing the dividing blepharoplast with the radiating cytoplasmic rays, × 300.

Fig. 15. The divided blepharoplasts have taken up a position which is at right angles to the long axis of the pollen tube. The tube nucleus and the prothallial cell are at the right upper corner. Note the stream of dark tiny particles in the cytoplasm of the body cell specially on either side of the upper blepharoplast. Their presence at this stage is inexplicable, × 300.

Fig. 16. The body-cell nucleus has become spindle-shaped before division. Note the chromosomes being organised inside it while the nuclear membrane is slowly disappearing, × 300.

Fig. 17. Portion of a spiral band forming an arc of a circle with one end still in contact with the nucleus of the sperm mother cell. The cilia are seen clearly, × 260.

Fig. 18. Portion of the spiral band which is in contact with the nucleus appears to merge into a vacuole, × 770.

Fig. 19. Portion of the spiral band very near the surface of the body cell. It appears to be cylindrical almost resembling a rope with several cords. Note the cilia on its outer side, × 520.

Plate XX

Figs. 20–31

Fig. 20. Another spiral band showing the free end with a knob-like enlargement. Cilia are seen, × 520.

Fig. 21. The body cell has divided into two sperm mother cells. The right-side mother cell nucleus clearly shows the attached end of the spiral band. Note the partition wall and the size relation between the nuclei and cytoplasm of the sperm mother cells, × 300.

Fig. 22. Portions of two spirals of a spiral band with number of dark bodies that are present in the sperm cytoplasm. Their function is not clear, × 520.

Fig. 23. An oblique view of a sperm from its apical end. Note the apex, number of coils of the spiral band and the cilia, × 260.

Fig. 24. Two sperms are organised one in each mother cell. The partition wall is clearly seen, × 300.

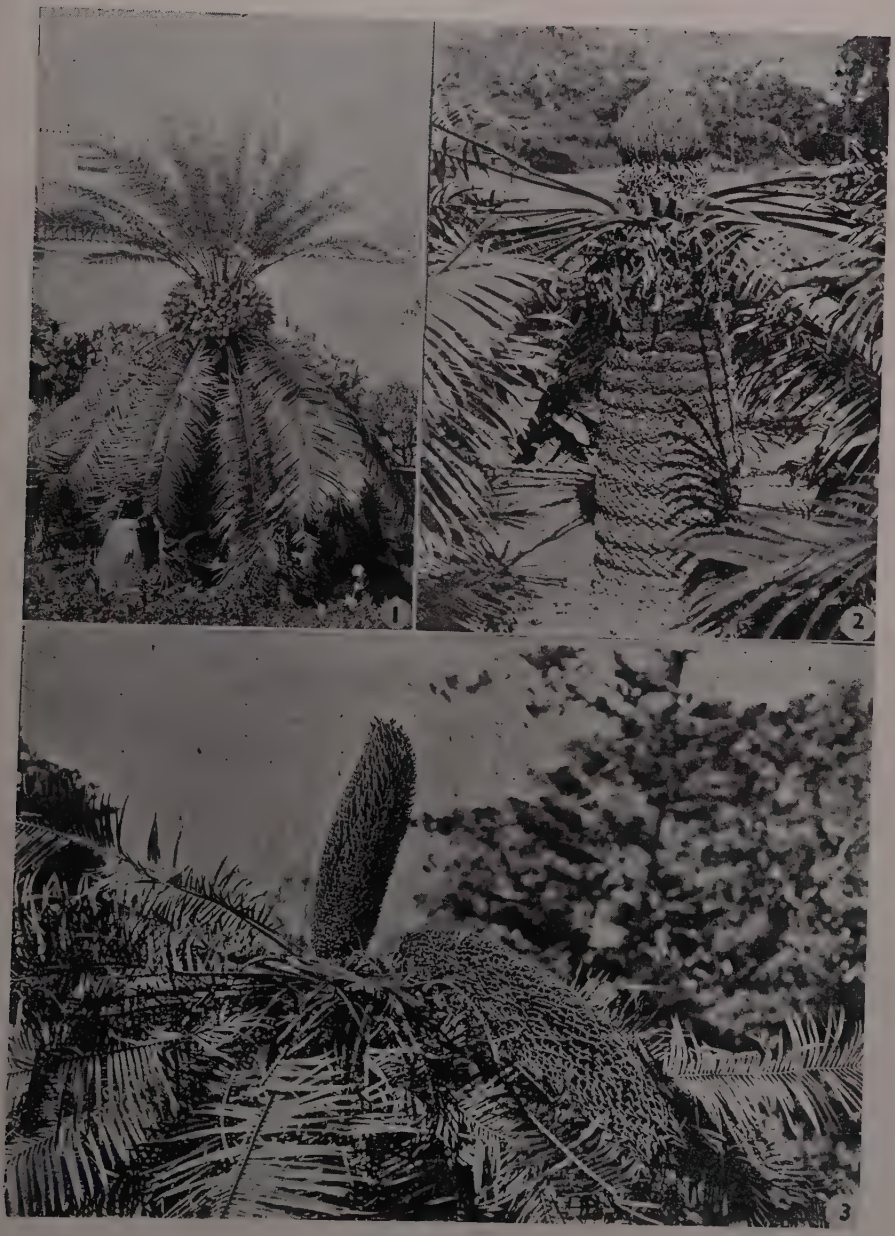
Fig. 25. One of the sperms highly magnified to show the median longisectional view. Note the apex of the sperm and five to six coils of the spiral band, × 520.

Fig. 26. A portion of a section of a sperm to show the position of the spiral band in a notch or a ledge on the surface of the sperm with cilia directed outwards, × 520.

Fig. 27. A median longisection of an ovule with the undifferentiated massive integument, enclosing the nucellus which is divided into the upper beak and the lower belly. The belly portion contains the free nuclear stage of the female gametophyte surrounded by the 'Endosperm Jacket', × 12.

Fig. 28. Section of an ovule slightly older than the previous one. The nucellar beak has its central tissue disorganised to form the extension of the pollen chamber. The female gametophyte has grown at the cost of the 'Endosperm Jacket' and has become cellular, × 12.

Fig. 29. The division of the central cell nucleus into the ventral canal nucleus and the egg nucleus. The anaphase stage of the nuclear division shows



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FIGS. 1–3

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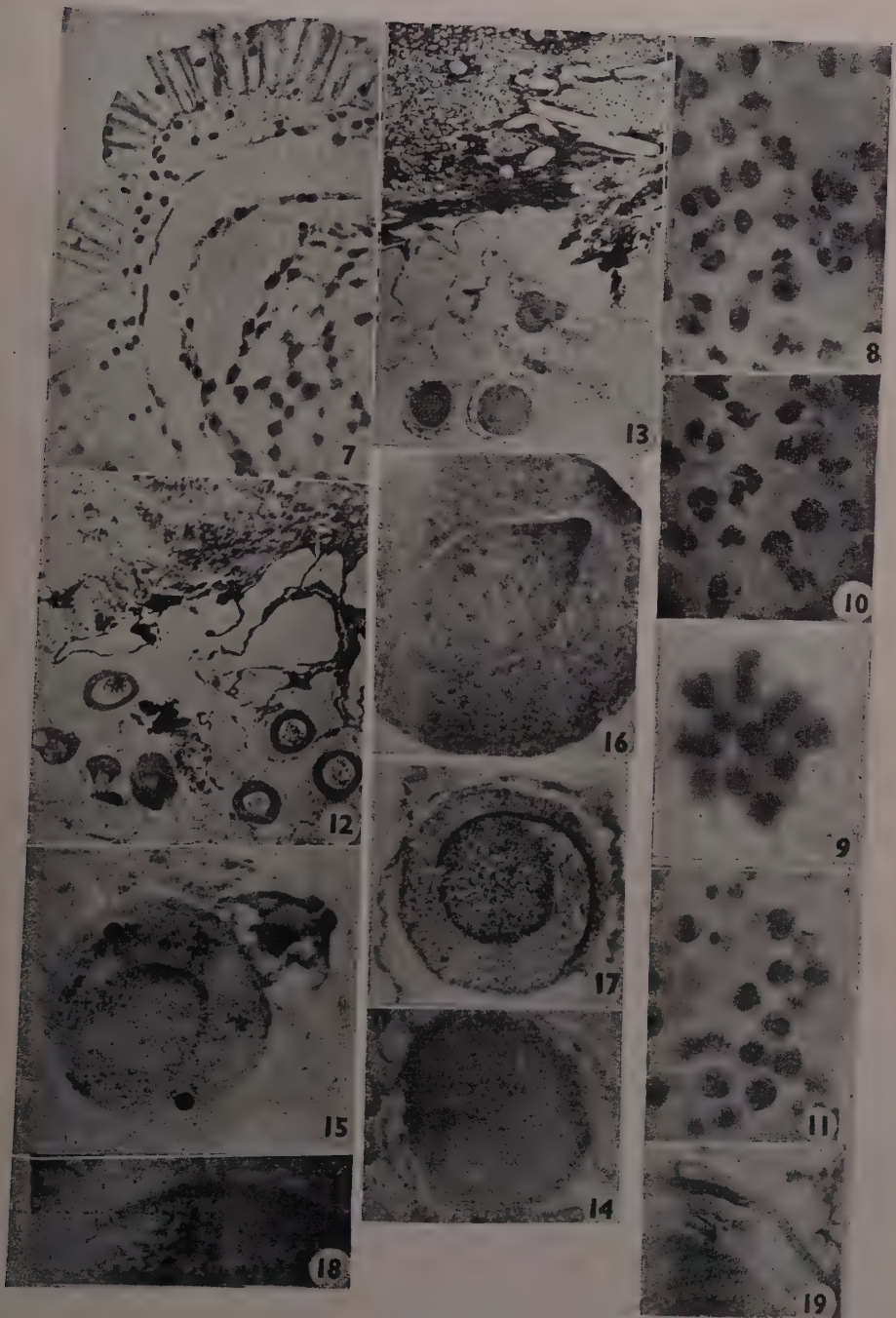
FIGS. 4–6



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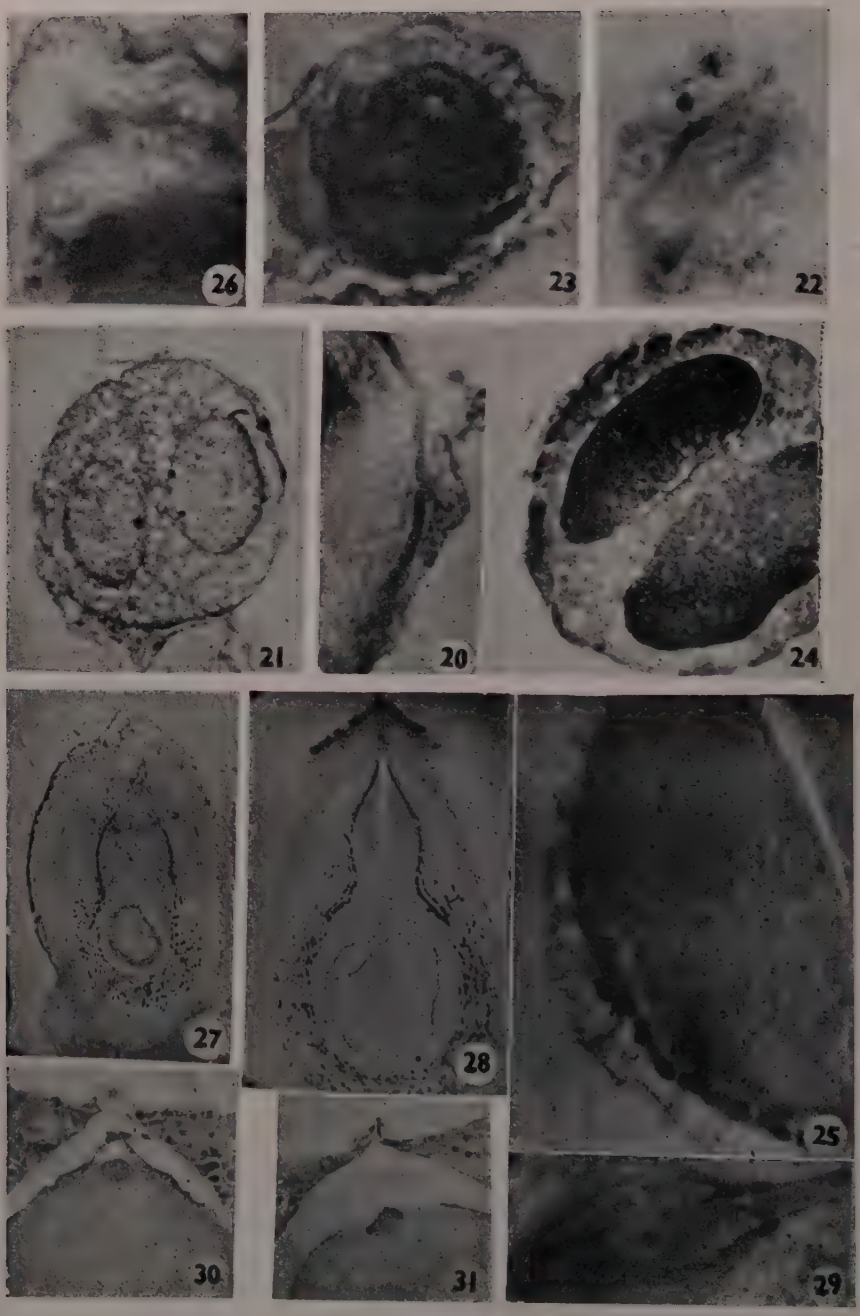
FIGS. 7–19



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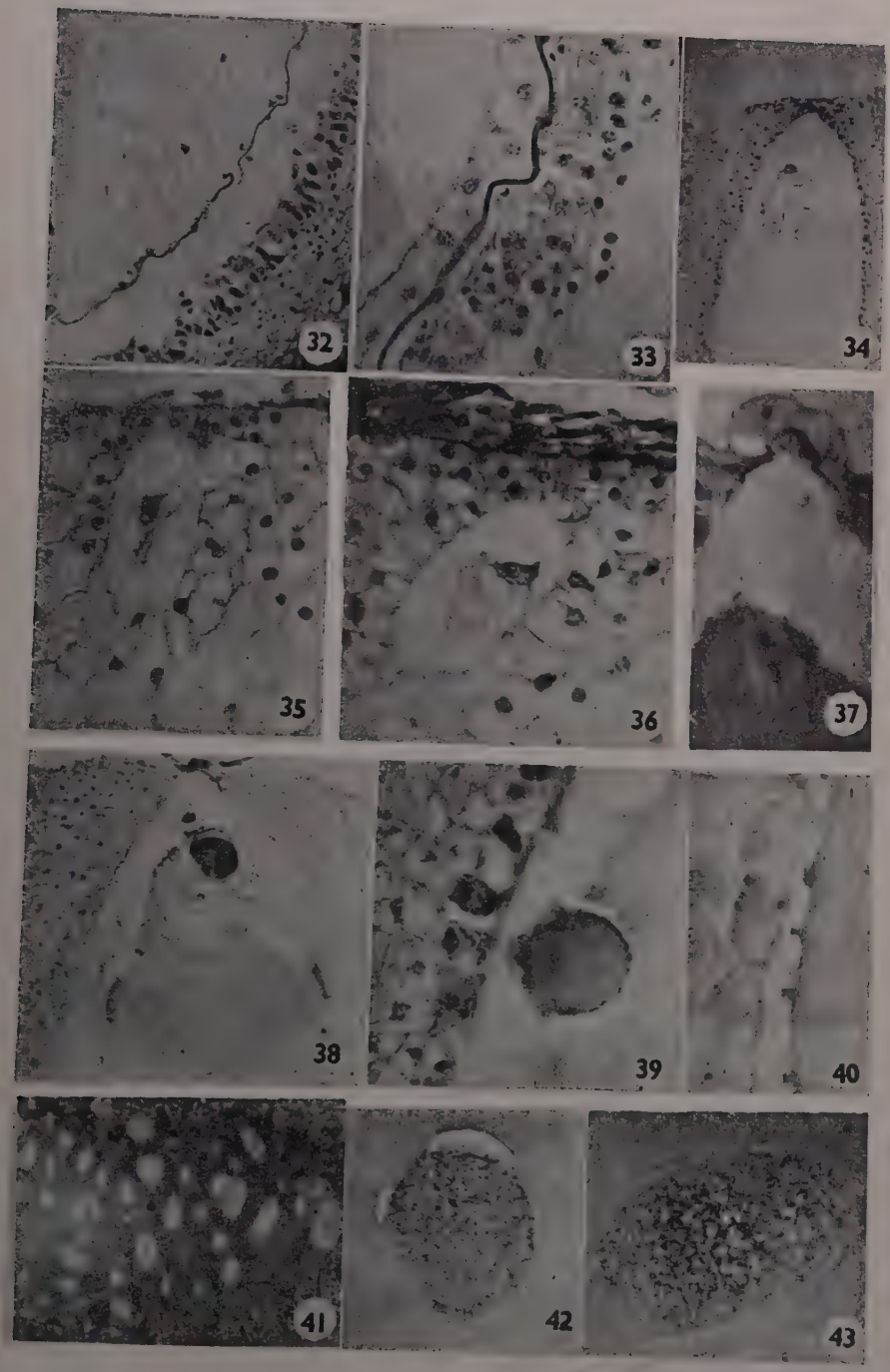
FIGS 20–31



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FIGS. 32–43

no sign of any partition. Hence, ventral canal cell as such is not formed, × 770.

FIGS. 30 and 31. Two stages in the extrusion and disorganisation of the ventral canal nucleus, × 65.

PLATE XXI

FIGS. 32–43

FIG. 32. Portion of a section of the female gametophyte showing the 'Endosperm Jacket', the megaspore membrane appearing like a thin dark wavy line broken here and there and a thick layer of cytoplasm with scattered nuclei along its periphery. The centre is occupied by a cavity filled with a clear liquid, × 82.

FIG. 33. An older stage than the previous stage. The nutritive jacket as well as the megaspore membrane are clearly seen. The female gametophyte has developed a layer of cells along the periphery with the central cavity filled with the liquid, × 170.

FIGS. 34–36. Stages in the development of the archegonium. Fig. 34, × 45. Fig. 35, × 75. In Fig. 36, the central cell and the neck cells are clearly seen. Just above the archegonium, the megaspore membrane and the remnants of the endosperm jacket cells are seen. Archegonial chamber has not developed at this stage, × 170.

FIG. 37. Upper portion of an archegonium showing the two neck cells and the division figure of the central nucleus, *cf.* Fig. 29, × 50.

FIG. 38. Upper portion of an archegonium showing the two collapsed neck cells and the two sperms that have entered, of which one has slipped out of its spiral band and merged with the cytoplasm of the egg. The dark lines or spots on either sides of the cytoplasm are the haustoria which have grown to wart-like structures, × 770.

FIG. 39. A sperm has got into the side of an archegonium and is lodged there between the archegonial jacket and the egg cytoplasm, × 50.

FIG. 40. The haustoria being slightly pulled out of their position by the receded cytoplasm. The corresponding pits can be seen just opposite on the egg membrane, × 130.

FIG. 41. The egg membrane develops pits which later on become pores by the disorganisation of the middle lamella. The pores are of different sizes. The surface view of them is shown, × 170.

FIGS. 42 and 43. Egg nucleus in contact with the sperm nucleus, × 82.

DEVELOPMENT OF EMBRYO IN THE CUCURBITACEAE

By Dalbir Singh

Botany Department, University of Rajasthan, Jodhpur

(Received for publication on June 7, 1960)

Introduction

The literature on embryogeny of the Cucurbitaceae is meagre and Johansen (1950) has rightly remarked that the affinities of this family are still dubious. Kirkwood (1905) stated that embryologically *Apodanthera undulata*, *Benincasa hispida*, *Bryonopsis laciniosa*, *Citrullus vulgaris*, *Cucumis myriocarpus*, *Cucurbita pepo*, *Lagenaria lagenaria* (*L. leucantha*), *Luffa acutangula*, *Melothria pendula*, *Micrampelis lobata*, *Momordica charantia*, *Sicyos angulata* and *Trichosanthes anguina* appeared to be more or less alike. The zygote undergoes a transverse division followed by another similar division resulting in a linear row of three or four cells. However, the zygote of *Sicyos angulata* divides by an oblique wall. In most of these genera more transverse divisions result in the increase of cells of the linear proembryo before any anticlinal walls are laid down. Tillman (1906), on the other hand, mentioned that in *Cucumis sativus* the basal cell does not divide further. The terminal cell divides vertically and one of the daughter cells forms an epiphysal cell by oblique division. Thus, the embryogeny is related to the Trifolium-variation of the Onagrad type. The embryonal development in *Bryonia dioica* (Souéges, 1939) follows the Myosurus-variation and in *Cucumis melo* var. *pubescens* (Singh, 1955) Nicotiana-variation of the Onagrad type. In view of these variations it was considered worthwhile to study the embryogeny of *Citrullus colocynthis* Schrad., *Dicaelospermum ritchiei* Clarke, and *Melothria maderaspatana* Cogn.

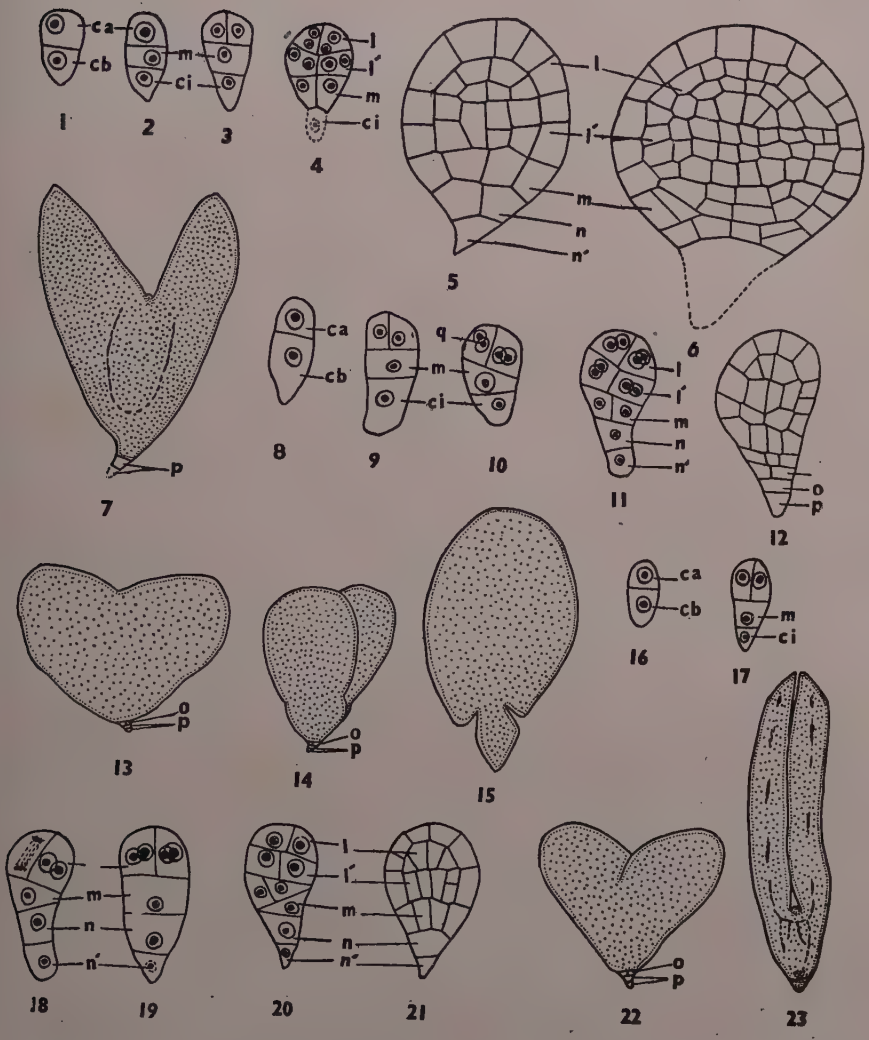
Materials and Methods

Citrullus colocynthis and *Melothria maderaspatana* were collected by me from Agra, while *Dicaelospermum ritchiei* was collected by Mr. S. N. Chaturvedi and Mr. O. P. Madhok from Pachmari.

Usual methods of fixing, dehydration, embedding, sectioning and staining were followed. Young and old embryos were also excised without any pre-treatment. These were stained with acetocarmine, mounted in glycerine and sealed with canada balsam.

Observations

The division of the zygote is transverse in all the three plants resulting in a terminal (*ca*) and a basal cell (*cb*) (Text-Figs. 1, 8, 16).



TEXT-FIGS. 1–23. Stages in the development of embryo; for explanation *see* text. Figs. 1–7. *Citrullus colocynthis* (Figs. 1–6, × 338; Fig. 7. Diagrammatic, × 42). Figs. 8–15. *Dicaelospermum ritchiei* (Figs. 8–12, × 338; Fig. 13, Diagrammatic drawn from whole mount, × 42; Figs. 14, 15 same, × 7). Figs. 16–23. *Melothria maderaspatana* (Figs. 16–20, × 338; Fig. 21, × 262; Fig. 22, Diagrammatic from whole mount, × 42; Fig. 23, × 5.5).

During further development *cb* divides transversely (Text-Figs. 2, 9, 10, 17), and *ca* by a vertical wall (Text-Figs. 3, 9, 17). The four-celled proembryo is thus T-shaped. Oblique or transverse divisions of *cb* has also been reported in *Bryonia dioica* (Souéges, 1939),

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The literature on embryogeny of the Cucurbitaceae is meagre and Johansen (1950) has rightly remarked that the affinities of this family are still dubious. Kirkwood (1905) stated that embryologically *Apodanthera undulata*, *Benincasa hispida*, *Bryonopsis laciniosa*, *Citrullus vulgaris*, *Cucumis myriocarpus*, *Cucurbita pepo*, *Lagenaria lagenaria* (*L. leucantha*), *Luffa acutangula*, *Melothria pendula*, *Micrampelis lobata*, *Momordica charantia*, *Sicyos angulata* and *Trichosanthes anguina* appeared to be more or less alike. The zygote undergoes a transverse division followed by another similar division resulting in a linear row of three or four cells. However, the zygote of *Sicyos angulata* divides by an oblique wall. In most of these genera more transverse divisions result in the increase of cells of the linear proembryo before any anticlinal walls are laid down. Tillman (1906), on the other hand, mentioned that in *Cucumis sativus* the basal cell does not divide further. The terminal cell divides vertically and one of the daughter cells forms an epiphysal cell by oblique division. Thus, the embryogeny is related to the Trifolium-variation of the Onagrad type. The embryonal development in *Bryonia dioica* (Souéges, 1939) follows the Myosurus-variation and in *Cucumis melo* var. *pubescens* (Singh, 1955) Nicotiana-variation of the Onagrad type. In view of these variations it was considered worthwhile to study the embryogeny of *Citrullus colocynthis* Schrad., *Dicaelospermum ritchiei* Clarke, and *Melothria maderaspatana* Cogn.

Materials and Methods

Citrullus colocynthis and *Melothria maderaspatana* were collected by me from Agra, while *Dicaelospermum ritchiei* was collected by Mr. S. N. Chaturvedi and Mr. O. P. Madhok from Pachmari.

Usual methods of fixing, dehydration, embedding, sectioning and staining were followed. Young and old embryos were also excised without any pre-treatment. These were stained with acetocarmine, mounted in glycerine and sealed with canada balsam.

Observations

The division of the zygote is transverse in all the three plants resulting in a terminal (*ca*) and a basal cell (*cb*) (Text-Figs. 1, 8, 16).

Explanation of Plates XVII–XXI

Plate XVII

Figs. 1-3

Fig. 1. Ovulate plant of *Cycas circinalis* showing the two sets of foliage leaves and the ovulate cone between them. The large number of ovules are produced as a result of artificial pollination.

Fig. 2. Another ovulate plant showing the ovulate cone with young ovules. Note the armour of leaf-bases forming rings round the cylindrical trunk. The sporophylls are compactly packed, only the ovules peeping out. Below the cone are the whorls of scale-leaves, foliage leaves and dried up sporophylls of previous season.

Fig. 3. A staminate plant of *Cycas circinalis* with two cones, one on the left is at the pollen shedding stage with the collected pollen mass on the dorsal side of the sporophylls while the one on the right has already collapsed.

Plate XVIII

Figs. 4–6

Fig. 4. Close up view of the cone in Pl. XVII, Fig. 1, before the appearance of the upper set of foliage leaves. Note the number of ovules and the tips of the megasporophylls with dentate margin.

Fig. 5. Ovulate cone of another plant shown in Pl. XVII, Fig. 2, at a late stage of development. Note the central vegetative bud covered by scale-leaves.

Fig. 6. Megasporophylls bearing from one to twelve ovules.

Plate XIX

Figs. 7–19

Fig. 7. Transverse section of a portion of the microsporangium, showing the wall layers, annulus, tapetum and the sporogenous tissue, × 200.

Fig. 8. First division of the meiosis. Note the spindle and the partition wall extending to the border and beyond the mother cell to form the phragmoplast, × 350.

Fig. 9. Eleven bivalents are seen and counted, × 1,200.

Fig. 10. Tetrads enclosed in mucliagenous martrix out of which the microspores slip out when mounted in water. The matrix is derived probably from the phragmoplasts, × 95.

Fig. 11. Germination of the microspores to form the two- and three-nucleate bodies, *i.e.*, the male gametophyte, × 350.

Fig. 12. Portion of the nucellar beak with number of pollen tubes invading it. At least seven tubes are there as determined by the number of body cells in the picture, × 60.

Fig. 13. Nucellar beak with the haustorial end of the pollen tubes ramifying its tissue, while the basal portions are in the pollen chamber. In one of the tubes, the body cell nucleus is in the division stage, × 60.

Fig. 14. Portion of the body-cell showing the dividing blepharoplast with the radiating cytoplasmic rays, × 350.

The observation on germination of the treated seeds in the pots has indicated (Table I) that at the lower concentration of 10 p.p.m. the germination has shown an increase of about 2–15 per cent. in all the three hormones, the highest being shown with I.A.A. In the next two concentrations of 50 and 100 p.p.m. there is a decrease in the percentage germination under I.A.A. and I.P.A. but the effect of N.A.A. does not show any steep fall.

Observations in Pot Experiment

Flowering umbels.—The number of flowering umbels did not show any consistent increase under the effect of hormones. However, the treatments T_2 I.A.A., T_3 I.P.A. and T_4 I.P.A. have indicated 3–15 per cent. increase (Table II).

Fruiting umbels.—Except at the concentration 50 p.p.m., there is a reduction in the number of fruiting umbels at both the remaining concentrations, *viz.*, 10 p.p.m. and 100 p.p.m. (Table II). The percentage increase over the control has ranged from 11–37 per cent.

Primary branches.—Like the fruiting umbels, the primary branches on the main stalk also show an increase in the treated plants at 50 p.p.m. with all the three hormones and the range in increase is found to be 14–31 per cent. over the untreated plants (Table II).

Fruit yield.—There is an overall increase in fruit yield of the cumin variety R.S. 1, when it has been treated with the hormones except for the treatments T_2 I.P.A., T_2 N.A.A. and T_4 I.A.A., where the decrease has ranged from 9–31 per cent. The highest increase in yield ranging between 44–97 per cent. have been exhibited, where the hormone concentration has been kept at 50 p.p.m. The same treatments have also shown the highest percentage increase for fruiting umbels and primary branches.

Discussion

Extremely poor germination of seeds is an intriguing problem in Umbelliferae. Percentage germination is reduced even up to 50 per cent., as has been observed in *Anethum graveolens* (Flemion and Waterbury, 1941). In the case of *Cuminum cyminum*, the present studies have shown 80 per cent. germination in Petri dish and in the pots the germination is only 45 per cent. Such a low germination of the seed effectively hits the cultivator as he has to use higher seed rates to ensure better and uniform crop stand. Low germination of the seeds in Umbelliferous crops has been variously interpreted, but Robinson (1954), in a review "Seed Germination Problem in Umbelliferae" has pointed out three possibilities for the failure of germination. They are (1) abortive embryo, (2) development of rudimentary embryo, where the seeds germinate only after a period of storage and (3) dormant embryos, which require specific light and temperature conditions for germination.

cyminum), an important cash crop of Rajasthan. The present paper deals with the effect of three hormones on germination, flowering, fruiting, branching and the yield of cumin variety R.S. 1.

Material and Methods

Variety R.S. 1, a high yielding strain, has been evolved by the Department of Agriculture, Rajasthan, from the local material collected within the State. The variety suits all places of cumin cultivation in Rajasthan.

Three hormones were used in this study, *viz.*, indol-3-acetic acid (I.A.A.), indolyl-3-propionic acid (I.P.A.) and naphthaleneacetic acid (N.A.A.). The fresh and healthy seeds of the variety, R.S. 1, were soaked in the aqueous solutions of these hormones at three concentrations, *viz.*, 10 p.p.m., 50 p.p.m. and 100 p.p.m. The duration of soaking the seeds was kept at 24 hours. Water-soaked seeds in distilled water and dry seeds as such were kept as controls. The seeds after treatment with hormones were thoroughly washed with tap-water before sowing.

Plants were raised in earthen pots of 18 inches diameter. Field soil from the plot, which was lying fallow in kharif, was used after proper sieving. Field soil and well-rotted farm-yard manure were thoroughly mixed in the ratio of 2 : 1 before using it in the pot. Two seeds were sown at each hill and there were five hills per pot. After the full development of the seedlings, five uniform seedlings were retained per pot. There were seven pots for each treatment.

In all there were eleven treatments having different hormonal concentrations:

	Treatment	Symbol
1.	Untreated seeds (Control)	T_0
2.	Water soaked (Distilled water)	T_1
3.	10 p.p.m. indolyl-3-acetic acid	T_2 I.A.A.
4.	10 p.p.m. indolyl-3-propionic acid	T_2 I.P.A.
5.	10 p.p.m. naphthaleneacetic acid	T_2 N.A.A.
6.	50 p.p.m. indolyl-3-acetic acid	T_3 I.A.A.
7.	50 p.p.m. indolyl-3-propionic acid	T_3 I.P.A.
8.	50 p.p.m. naphthaleneacetic acid	T_3 N.A.A.
9.	100 p.p.m. indolyl-3-acetic acid	T_4 I.A.A.
10.	100 p.p.m. indolyl-3-propionic acid	T_4 I.P.A.
11.	100 p.p.m. naphthaleneacetic acid	T_4 N.A.A.

EFFECT OF CERTAIN HORMONES ON GERMINATION, FLOWERING, FRUITING, BRANCHING AND YIELD OF CUMIN (*CUMINUM CYMINUM*)

By S. M. Gandhi and M. P. Bhatnagar

Agriculture Research Station, Durgapura (Rajasthan)

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Introduction

Presence of growth hormones in the plant tissues, introduced either by seed soaking or by spraying, has been found to have striking effect on plant growth and development and this has been particularly observed in the case of α-naphthaleneacetic acid by Naundorf and Oliver (1949). Brevieri (1948) observed excessive root initiation and development and growth of fruits without pollination with a number of other hormones like indole-3-acetic acid, indolebutyric acid, β-naphthoxyacetic acid, 2, 4-D, α-naphthaleneacetic acid and 2, 3, 5-trichlorophenoxyacetic acid. Voluminous literature is now available on the effect of hormones on plant parts, reproduction and their physiology. The most up-to-date review in India has recently been written by Maheshwari (1957). Apart from other effects of hormones like production of seedlessness, introduction of male sterility, prevention of preharvest drop of fruits and many others, the most fascinating researches in the field of agriculture had mainly been in their contribution for getting increased yields in crop plants.

In India quite an exhaustive work has been accomplished and the working groups engaged in this research have explored many crops like jowar, wheat, gram, cotton, sugarcane and groundnut for the effect of hormones either by seed treatment or by spraying the seedlings.

Significant contribution in this respect has been advanced from the Agriculture Department, Bombay, where the investigations for the last three years have shown that there is no appreciable increase in seed yield of the crops like jowar, wheat, gram and groundnut, when seeds treated with 2, 4-D were sown but, on the other hand, hormonal effect had been very prominent in increasing the root system and vegetative growth of the plants. The latter finding has now diverted the attention to those crops where vegetative growth is more useful and of greater economic importance. In addition to this, unexplored crops, which have not yet been tapped under this experimentation, can also be expected to give some useful indications. Studies were, therefore, taken up to investigate the influence of hormones on cumin (*Cuminum*

have petiolate leaves, and none of the tips of the branches are puberulous. Considering these facts, the var. *puberula* is distinct in having all parts of the twigs puberulous, only the midrib being prominent, perianth lobes being puberulous on the outisde, and their leaves are smaller in size compared with those of the species. Since the variety is thus distinct, an amplified description of it, based on the specimens examined by me, was thought desirable, and is given below.

Semi-parasitic shrubs. Branches and all other parts puberulous. Old twigs drying dark, angled or rounded, cortex cracking into rectangular areas; and having a number of ridges, the ridges more puberulous than the depressions. Twigs at extremities rounded, with ridges less prominent than in old. All parts of the twigs equally finely puberulous. Leaves alternate, exstipulate, petiolate, ovate to elliptic oblong, entire, attenuate, mucronate, with a single prominent vein from base to tip on the underside. All parts of the leaf finely puberulous, and the leaves drying reddish or slightly olive green. Leaves from $4{\cdot}5\times3{\cdot}0$ to $0{\cdot}75\times0{\cdot}4$ cm., petiole up to 0·4 cm. Male flowers in peduncled axillary inflorescences, the flowers very small and often in groups of three; bracteolate and trimerous. The inflorescence as well as the flowers are again equally finely puberulous. Tepals triangular, concave, puberulous on the outside, and enclosing a prominent triangular disc in the middle. Stamens opposite the tepals, each with a short stout stalk capped by two thecae, dehiscence transverse. Female flowers mostly solitary, axillary, pedicelled, 0·8 cm. long, the pedicel and flower of equal length. Urceolate perianth (tepals) adnate to the ovary, lobes three, valvate. All parts of the female flower again finely puberulous; the white hairs many, simple, sometimes with bulbous bases. Young fruit 0·4 cm. long, 0·3 cm. wide, also with simple white puberulence, the disc prominently seen on top of the fruit.

2. ***Dendrophthoë gibbosa* (Talbot) Razi** in *Lloydia* **20**: 242, 1957. *Loranthus gibbosus* Talbot, *List. Tr., Bombay* **20**: 289, 1902; T. Cooke, *Fl. Bombay* **2**: 547, 1908; Talbot, *For. Fl. Bombay* **2**: 409, 1911; Fischer, *Rec. Bot. Surv. India* XI, **1** (2): 174, 1926.

Specimens examined: (i) Bombay: Goa boundary at Londa, *Fernandez*, No. 1326, Aprill 22, 1950, deposited at Arnold Arboretum, Cambridge, Massachusetts; (ii) Yellapur, *Talbot* No. 778, cold season-1884; (iii) Yellapur, *Talbot*, November 18, 1900; (iv) Yellapur, *Talbot*; (v) Yellapur, *Talbot*; (vi) Ainshy, North Kanara District, *Talbot*, No. 1855, February 11, 1889; (vii) Harnadgi, Belgaum District, *Talbot*, No. 3827, May 8, 1897. Nos. (ii) to (vii) deposited at the Herbarium of the Regional Botanist, Botanical Survey of India, Western Circle, Poona.

Danser (1929, 1933) not having seen specimens of this species has excluded it from his nomenclators. However, these specimens examined by me key down to *Dendrophthoë*.

In Kew Herbarium there are three sheets which are doubtfully named ?*Taxillus heyneanus* (Schult) Dans., by Danser (23–4–1938),

NOTES ON PARASITIC PLANTS FROM INDIA AND PAKISTAN

By Basheer Ahmed Razi

Department of Botany, Central College, Bangalore

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While annotating material of phanerogamic parasites from India and Pakistan available at American Herbaria, the author (Razi, 1957) proposed some new combinations to bring the nomenclature in conformity with International Rules. Brief notes to accompany the emended descriptions of these combinations are given below:—

1. ***Osyris wightiana* Wall. var. *puberula* (Hook.f.) Razi** in *Lloydia* **20:** 279, 1957. *Osyris arborea* Wall. var. *puberula* Hook.f. in *Fl. Brit. India* **5**: 232, 1886.

Specimens examined: (i) East Satpura hills, *R. Thomson* ; this bears University of Chicago Number 374774, and is now deposited at the Chicago Natural History Museum; (ii) Nilgiris, *Jerdon*; (iii) Coonoor at 6,000′, *C. B. Clarke*; (iv) Madhya Pradesh, *J. F. Duthie*; Nos. (ii) to (iv) deposited at Kew.

These specimens appear to be quite different from ***Osyris wightiana*** in being finely puberulous all over, and their flowers appear different too. Hooker in *Fl. Brit. India* **5**: 232, 1886 has included them under *Osyris arborea* Wall. var. *puberula*, the variety differing from the species in having branches and leaves finely puberulous. It is said to occur in the Nilgiris (Jerdon) at Coonoor; and also in Central Provinces (now named Madhya Pradesh) (Thomson, Brandis). Hooker (*l.c.*) says he has not seen specimens of this variety from the Central Provinces. Apparently the specimen (i) cited above is one of the specimens he has not seen. Among the sheets available at Kew, those collected by Duthie in Central Provinces approximate most closely the East Satpura specimens; and on the Coonoor sheet (No. iii above cited), C. B. Clarke remarks "this species differs by the hairy stems and leaves from ***Osyris wightiana***". All the above cited specimens have the puberulence in common and on that account belong to var. ***puberula*** Hook.f. Furthermore, according to Hooker (*l.c.*) *Osyris* is glabrous, the perianth lobes have a tuft of hairs on the face; and in *Osyris arborea* (= ***Osyris wightiana***) the leaves are subsessile, the tips of the branches puberulous, leaves very variable in width, thickly coriaceous, midrib and nerves prominent beneath or the latter faint.

All specimens of *Osyris wightiana* examined by me are glabrous, and their perianth leaves do not have a tuft of hairs on the face. They

Hormones have also been thought of as possible agents for stimulating the germination of seeds but the results so far achieved are not conclusive (Maheshwari, 1957). In the present studies hormone effect on germination has provided very interesting results. Under the continuous soaking treatment, indolyl-3-propionic acid has acted as deterrent in restricting the germination under all the three concentrations. The other two hormones, *viz.*, I.A.A. and N.A.A., have reacted favourably at low concentration of 10 p.p.m., where it is observed that germination has increased by 5 per cent. over the control.

Percentage germination observed in the pot experiment, when 24 hours soaked seed was sown, has indicated that lower concentration at 10 p.p.m. of all the three hormones has been helpful in getting increased germination over the controls. The hormone 3-indolylacetic acid has given about 15 per cent. higher germination than the control. The hormone I.P.A., which proved harmful under continuous soaking even at low concentration, had stimulated seed germination, when an initial presoaking treatment was provided.

It seems possible from the present studies that hormones at lower concentration of 10 p.p.m. may prove effective in increasing the germination of the cumin seed, if a presoaking treatment of 24 hours can be provided. Continuous soaking provides an inhibitory effect on germination, which of course, is less pronounced at lower concentration in I.A.A. and N.A.A. than at the higher ones.

Another important limitation in Umbelliferous crops is higher flower/fruit ratio. Whatever flowering umbels are formed on the plant, they all do not necessarily set fruits thus, the yield component tends to remain lower at the higher flower/fruit ratio (Table II).

Observations made on the effect of flower/fruit ratio and the number of primary branches on the yield of cumin showed that as the flower/fruit ratio decreased and the number of primary branches increased, the fruit yield also showed a tendency to increase. This possibility suggests that the characters flower/fruit ratio and the number of primary branches are closely related to the yield of cumin. By obtaining the increasing value in the number of primary branches and decreasing ratio of flowers and fruits, a direct gain in the yield of the crop may possibly be obtained. Khan and Jalis (1957) in their studies with coriander and fennel have indicated that increase in seed yield was associated with increase in number of primary branches and plant height in these crops.

As regards the effect of hormones, there is no substantial increase in the number of flowering umbels per plant, but the effect is very pronounced in the case of fruiting umbels, number of primary branches and finally the fruit yield. All the three hormones at 50 p.p.m. concentration have provided 11–37 per cent. increase in fruiting umbels, 14–31 per cent. increase in primary branches and about 100 per cent. increase in fruit yield. Rest of the two concentrations, *viz.*, 10 p.p.m. and 100 p.p.m. have shown reduction in primary branches, fruiting umbels

and the yield except for the treatments T_2 I.A.A., T_4 I.P.A. and T_4 N.A.A., which have given 10–27 per cent. increase in yield.

Summary

A pot experiment was conducted to see the effect of three hormones, *viz.*, indolyl-3-acetic acid, indolyl-3-propionic acid and naphthaleneacetic acid at three concentrations of 10 p.p.m., 50 p.p.m. and 100 p.p.m. on the cumin variety R.S. 1.

Germination of cumin seed has been enhanced at the lower concentration (10 p.p.m.) of the hormones under both the treatments, *viz.*, continuous soaking and soaking for 24 hours, except for the hormone I.P.A., which has acted as deterrent under continuous soaking for all the three concentrations. Effect of hormones has been very pronounced in increasing the yield of cumin. All the three hormones at 50 p.p.m. have provided 11–37 per cent. increase in the number of fruiting umbels, 14–31 per cent. increase in the number of primary branches and about 100 per cent. increase in fruit yield per plant. With the decrease in flower/fruit ratio and the increase in the number of primary branches, the fruit yield has also shown a tendency to increase. Obviously these indices are very helpful in breeding high yielding varieties of cumin.

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A CONTRIBUTION TO THE FLORAL MORPHOLOGY AND EMBRYOLOGY OF *FAGONIA CRETICA* LINN.

By N. C. Nair* and Ishwari Gupta

Department of Botany, Birla College, Pilani, India

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The Zygophyllaceae comprise about 22 genera and 160 species of mostly woody, xero- and halophytic perennials, distributed in the tropics and sub-tropics of both the hemispheres (*see* Willis, 1955). Our information on the embryology of the family is very meagre. Schürhoff (1924, 1926) gave a fragmentary account of the gametophytes of *Tribulus terrestris*. In this plant the inner integument forms the micropyle and the development of the embryo-sac conforms to the Polygonum type (*cf.* Maheshwari, 1950). Souèges (1952, 1953 *a*, *b*, *c*) studied the development of embryo in *Tribulus terrestris*, *Zygophyllum fabago* and *Peganum harmala*. According to him the genus *Peganum* should be treated under a separate family Peganaceae.

Nair and Jain (1956) studied the embryology of *Balanites aegyptiaca* (syn. *B. roxburghii*) and suggested a detailed embryological study of the Zygophyllaceae. In *Balanites* the tapetal cells of the anther are binucleate and the mature pollen grains are 3-celled. Both the integuments take part in the formation of the micropyle. The nucellus is weakly developed and the inner epidermis of the inner integument transforms into an endothelium. The polar nuclei are unequal in size.

Material and Methods

Fagonia cretica is a small spiny herb commonly found in stabilized soil of Rajasthan desert. It flowers throughout the year but more profusely during the cold season. The material was collected at Pilani and neighbouring places and fixed in formalin-acetic-alcohol. The usual method of dehydration and embedding was followed. Sections were cut at 8 to 14 microns and stained with safranin and fast green, and iron-haematoxylin counterstained with alcoholic fast green.

Floral Morphology

The solitary terminal flower is pentamerous with imbricate sepals and petals. The sepals are persistent and not caducous as reported by

* Now at the Botanical Survey of India, Northern Circle, Dehra Dun.

Hooker (1875). The obdiplostemonous androecium bears dithecous, introrse anthers. There is an intrastaminal disc at the base of the ovary. The gynoecium is pentacarpellary and the 5-ridged pentalocular ovary contains two ovules in each loculus on axile placenta. The short style terminates in a simple, glandular stigma. All the floral parts are covered with unicellular hairs which arise as small protrusions from the epidermal cells and enlongate considerably (Text-Figs. 2, 3). The floral organs arise in acropetal succession (Text-Fig. 1).

Microsporangium and Microsporogenesis

A young anther is 4-lobed and the anther wall consists of 5 to 6 layers (Text-Fig. 4). The sub-epidermal layer develops into the fibrous endothecium after the differentiation of uninucleate pollen grains. The innermost layer functions as the secretory tapetum and its cells remain uninucleate throughout. The middle layers collapse during microsporogenesis so that the mature anther wall comprises only the epidermis and the endothecium (Text-Fig. 14).

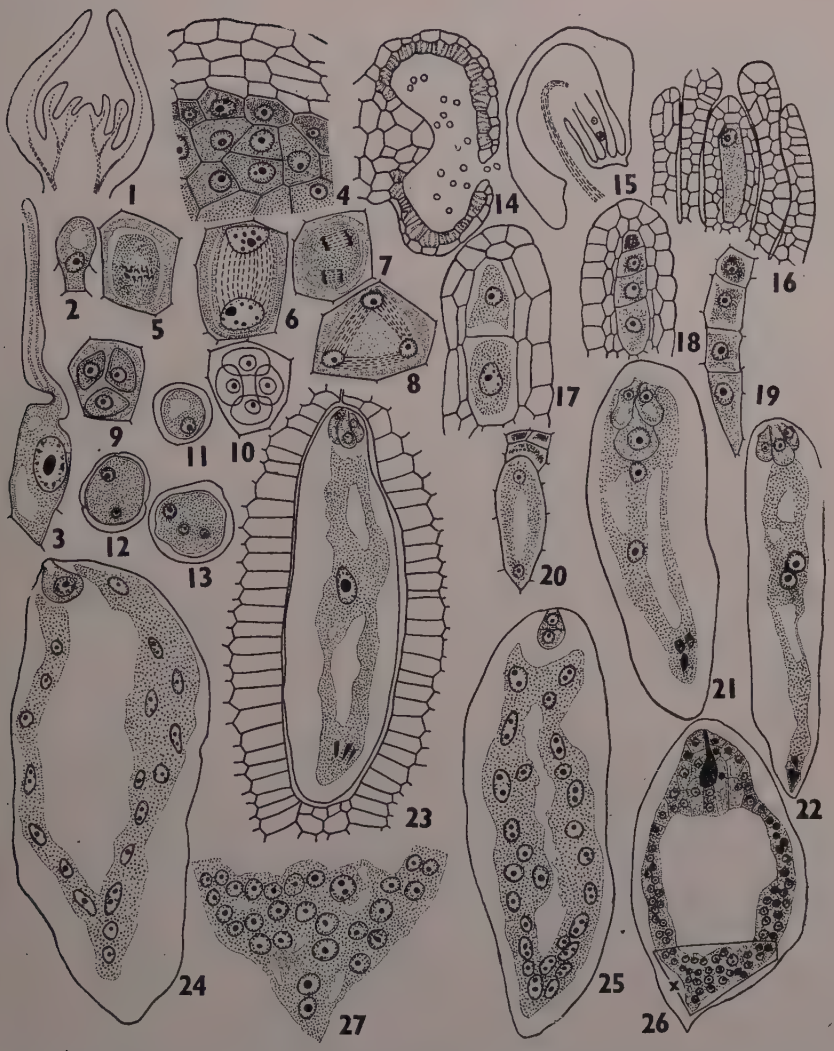
There are 2 to 3 rows of microspore mother cells in each lobe of the anther. They secrete a special mucilaginous wall inner to the original mother wall and it is absorbed during the enlargement of microspores. The latter are liberated due to the breaking down of the original mother wall. The reduction divisions are simultaneous (Text-Figs. 5–8) and there is a brief period of inter-kinesis after Meiosis I. During homotypic division the spindles may lie parallel or at right angles to each other and cytokinesis takes place by centripetal furrows. The tetrads are mostly tetrahedral but sometimes they may be decussate (Text-Figs. 9, 10).

Male Gametophyte

The young microspore has a large nucleus and dense cytoplasm. Its wall differentiates into the exine and intine. As the pollen grain enlarges, a large vacuole appears in the centre pushing the nucleus to one side (Text-Fig. 11) where it divides forming a small generative and a large tube cell (Text-Fig. 12). These are separated by an ephemeral membrane. Due to the disorganization of the latter the generative cell moves up, comes to lie close to the vegetative nucleus and produces two male gametes (Text-Fig. 13). The 3-celled pollen grains are of the psilate type and show 3 germ pores.

Megasporangium

The ovules are anatropous, bitegmic and crassinucellate. The micropyle is formed by the inner integument only (Text-Fig. 15). The ovular primordium is at first straight and later on curves towards the placental side. Text-Figure 16 shows a megaspore mother cell covered over by a parietal layer. Rarely two megaspore mother cells were observed lying one above the other (Text-Fig. 17). However, no case of twin embryo-sacs was observed in the present study. The megaspore mother cell undergoes the usual reduction divisions producing a linear



TEXT-FIGS. 1–27. Fig. 1. L.S. young flower-bud, × 12·5. Figs. 2, 3. Development of hair, × 12·5. Fig. 4. Part of anther in L.S. showing the wall layers and the microspore mother cells, × 375. Figs. 5–8. Microsporogenesis, × 375. Figs. 9, 10. Microspore tetrads. × 375. Figs. 11–13. Stages in the development of the pollen grains, × 375. Fig. 14. T.S. of mature anther, × 156. Fig. 15. L.S. of ovule at the mature embryo-sac stage, × 12·5. Figs. 16, 17. Megaspore mother cells, × 375. Figs. 18, 19. Linear tetrads, × 375. Figs. 20–23. Development of embryo-sac, × 375. Figs. 24–26. Development of endosperm. Figs. 24, 25, × 375. Fig. 26, × 156. Fig. 27. Portion marked × in Fig. 26 enlarged, × 375.

or T-shaped tetrad of which the chalazal megaspore is functional (Text-Figs. 18–20). As in *Tribulus terrestris* (Schnarf, 1931) and

Balanites aegyptiaca (Nair and Jain, 1956), the development of the embryo-sac conforms to the Polygonum type (Text-Figs. 20–22). The egg apparatus shows the usual organization (Text-Figs. 21, 22), the polar nuclei fuse in the centre of the sac (Text-Figs. 22, 23) or adjacent to the egg apparatus, and the antipodal cells degenerate early.

The enlarging embryo-sac crushes the adjoining nucellar tissue and comes to lie close to the inner integument whose inner epidermis transforms into an endothelium (Text-Fig. 23). Its cells remain uninucleate.

Endosperm

Whereas the upper part of the embryo-sac broadens after fertilization, the lower end remains narrow and elongate towards the chalaza. The primary endosperm nucleus divides earlier than the zygote (Text-Figs. 24, 42) and the endosperm is of the nuclear type. At the time of division of the zygote there are nearly 16–32 free endosperm nuclei (Text-Fig. 25) disposed in a peripheral layer of cytoplasm. There is an aggregation of nuclei at the chalazal end (Text-Figs. 24, 25). Centripetal wall formation is initiated in the neighbourhood of the embryo and progresses downwards till the whole of the endosperm becomes cellular (Text-Figs. 26–32, 46, 48). In the chalazal region the endosperm cells are multinucleate and richly cytoplasmic (Text-Figs. 29, 32). Very often the nuclei fuse to form irregularly lobed polyploid nuclei (Text-Fig. 32). In older stages the nuclei in the cells at chalazal end degenerate (Text-Fig. 32).

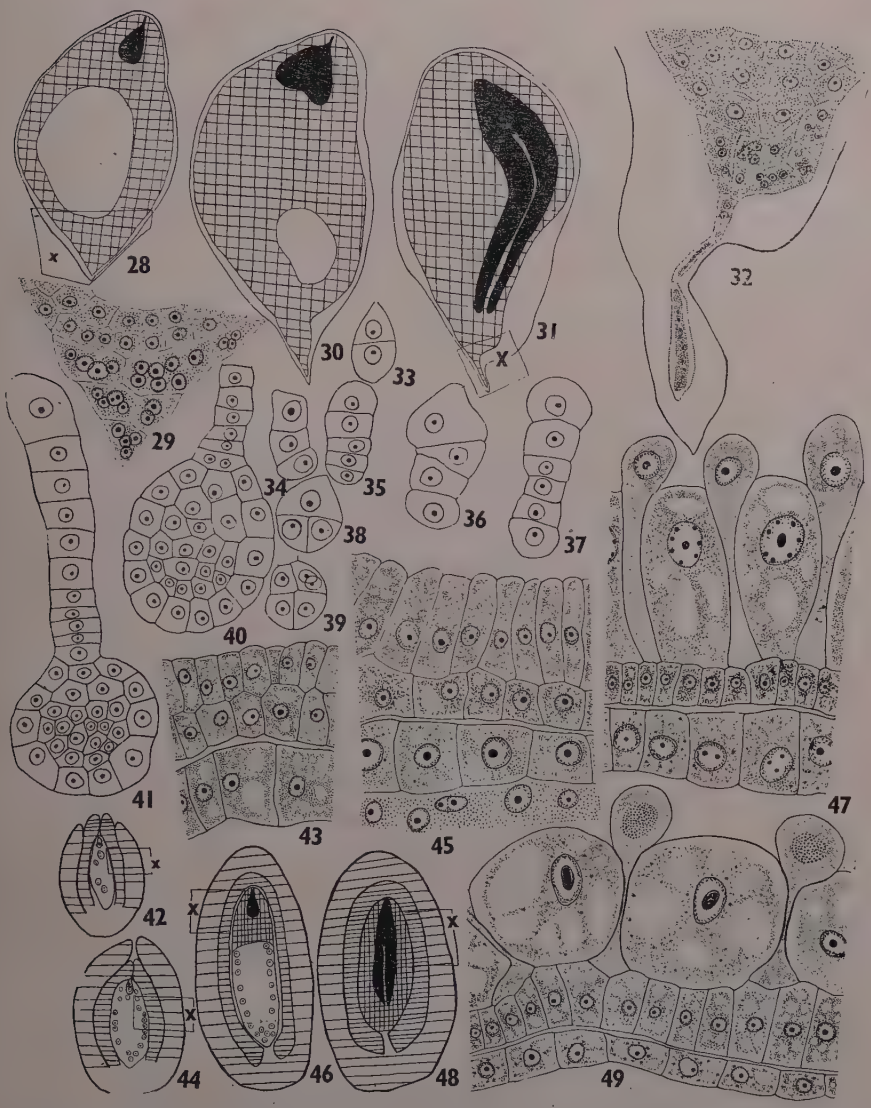
Embryo

The zygote enlarges and divides transversely to form a basal cell and an apical cell (Text-Fig. 33). The apical cell usually undergoes another transverse division (Text-Fig. 34). Occasionally it may divide vertically (Text-Fig. 38). The middle cell and the derivatives of the basal cell constitute the long suspensor. The embryo proper is derived from the apical cell alone. Text-Figures 43–52 show stages in the development of the embryo. The mature embryo is dicotyledonous (Text-Figs. 31, 48).

Seedcoat

Both the integuments take part in the formation of the seedcoat. Each integument is 2- to 3-layered in the beginning but after the disorganization of the endothelium only the outer epidermis of the inner integument persists (Text-Figs. 43, 45, 46, 49).

The cells of the inner epidermis of the outer integument elongate. The outer epidermal cells elongate radially and become palisade-like (Text-Fig. 45), and their cytoplasm becomes vacuolate. Some of them undergo further enlargement at about the globular stage of the proembryo (Text-Fig. 47). Because of the pressure exerted by these cells the intermediate cells become flattened and their contents are pushed into



TEXT-FIGS. 28–49. Figs. 28, 30, 31. Stages in the development of the endosperm, × 156. Figs. 29, 32. Portions marked × in Figs. 28 and 31 enlarged, × 375. Figs. 33–41. Stages in the development of the embryo, × 375. Figs. 42, 44, 46, 48. Stages in the development of the seed, × 69. Figs. 43, 45, 47, 49. Portions marked × in Figs. 42, 44, 46, 48 enlarged, × 375.

the knob-like protrusions (Text-Fig. 49). These cells finally assume glandular appearance and are responsible for the production of mucilage when the seeds are moistened.

Summary

In *Fagonia cretica* the floral organs arise in acropetal succession. The flower is pentamerous with obdiplostemonous stamens and a pentacarpellary gynoecium. There are two ovules on an axile placenta in each loculus. The anther wall consists of the epidermis, fibrous endothecium, 2-3 middle layers, and the glandular tapetum. Of these, only the endothecium and epidermis persist in the mature anther.

The reduction divisions in the microspore mother cells are simultaneous and the tetrads are mostly tetrahedral. The pollen grains are shed at the 3-celled stage.

The ovules are anatropous, bitegmic and crassinucellate. The cells of the inner epidermis of the inner integument give rise to an endothelium.

The development of the embryo-sac is of the Polygonum type. The endosperm is nuclear and centripetal wall formation is initiated at the micropylar end progressing downwards. Some of the endosperm cells at the chalazal end are multinucleate. The embryo proper develops from the apical cell of the 3-celled proembryo.

The seedcoat is derived from both the integuments and comprises 3–4 layers—outer epidermis of the inner integument and 2–3 layers of the outer integument.

Acknowledgement

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IMPORTANCE OF LESION WIDTH IN ASSESSING RESISTANCE OF SUGARCANE VARIETIES TO RED ROT [*GLOMERELLA TUCUMANENSIS* (SPEG.) ARX AND MUELLER]

By K. V. Srinivasan

Sugarcane Breeding Institute, Coimbatore-7

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Red rot of sugarcane is a disease of seedpieces in Louisiana and a laboratory technique employing cut pieces of cane is employed there for testing resistance (Abbott, 1938). In India, the disease being one affecting the standing crop, a field technique involving inoculation of standing canes is employed (Chona, 1954). In practice, the reaction of the varieties tested is assessed on the average length attained by the lesion after a predetermined period of incubation following inoculation (Chona, 1954; Anon, 1958). Experience at this Institute has shown that the average length of lesion, employed as the sole criterion of susceptibility, is liable to lead to erroneous conclusions. Resistance to red rot is known to be derived from both anatomical and physiological features of the host (Edgerton, 1958). As resistance offered by nodal tissues to the passage of the pathogen from one internode to the next would substantially affect the total lesion length attained, lesion length *per se* should not have much significance unless it is related to the number of internodes involved particularly in view of the known relative lack of resistance to longitudinal spread of the lesion within the internode in the generality of varieties as also of the striking variation in internodal length from variety to variety.

Another feature of resistance, and from our experience a more important one, involves the reaction of the parenchyma tissues to the lateral spread of the pathogen. Thus in several varieties the lesion is narrow and often consists of only thin streaks confined to one or a few vascular strands, running through one or several internodes beyond the inoculated internode (*e.g.*, in Co. 950). These streaks are attended by the development of gums in the intercellular spaces as also within the parenchyma cells adjoining the fibro-vascular bundles to a depth of 3 to 10 cell layers, and are consequently of a dark red colour. Such narrow lesions either do not bear or bear only small white spots in a background of dark red tissue. On the other hand, in other varieties (*e.g.*, in Co. 940, Co. 951), the lesion advances on a broad front through successive internodes and in such cases the lesion is a light red mottle interspersed with typical white transverse spots which are prominent and large. Re-isolations made in this laboratory from the former type

TABLE I

Lesion dimensions of Glomerella tucumanensis *(Strain D) in relation to damage caused in sugarcane varieties*

Variety	Total number of inter-nodes	Number of inter-nodes tra-versed by lesion	Lesion length in inches	Ratio of lesion width/cane width at		State of tops at the end 5 months
				3 months	5 months	
Co. 359	13	6	27	0·3	0·4	Green
Co. 432	17	9	28	0·3	0·4	,,
Co. 676	12	7	22	0·3	0·5	,,
Co. 789	14	7	28	0·3	0·3	,,
Co. 617	14	8	32	0·4	0·4	,,
Co. 644	12	6	25	0·4	0·4	,,
Co. 357	14	6	19	0·5	0·5	,,
Co. 416	13	5	17	0·5	0·5	,,
Co. 635	16	5	17	0·5	0·5	,,
Co. 658	18	5	24	0·5	0·5	,,
Co. 862	11	6	34	0·5	0·5	,,
Co. 884	15	5	26	0·5	0·5	,,
Co. 899	15	5	18	0·5	0·5	,,
Co. 889	20	7	23	0·7	0·9	Dried
Co. 613	17	7	26	0·8	1·0	Green, but extensive rotting of cane tissue.
Co. 410	10	5	18	0·9	1·0	Dried
Co. 475	10	6	39	0·9	1·0	,,
Co. 341	10	5	33	1·0	1·0	,,
Co. 355	12	5	29	1·0	1·0	,,
Co. 356	18	8	41	1·0	1·0	,,
Co. 625	10	5	20	1·0	1·0	,,
Co. 640	14	5	25	1·0	1·0	,,
Co. 649	14	6	22	1·0	1·0	,,
Co. 661	11	5	30	1·0	1·0	,,
Co. 670	10	6	20	1·0	1·0	,,
Co. 718	10	5	25	1·0	1·0	,,
Co. 757	8	5	24	1·0	1·0	,,

of lesion in several varieties yielded the pathogen in 0 to 12% of the number of transplants, while in the latter type of lesion successful re-isolations could be made from 85 to 100% of the transplants, indicating the lethal effects of the gummy substances. It would thus appear that circumscription of the lesion width, which is apparently brought about by a hyperergic (Gäumann, 1946), gummy, physiologic response on the part of the parenchyma cells, is indicative of a high degree of resistance.

Repeated observations have revealed that the lesion assumes its characteristic type (not always in the inoculated internode which may be more or less completely necrosed and decayed, no doubt on account of the high inoculum potential introduced, aided by the severe inoculation injury), but invariably in the adjoining one or two internodes if the disease lesion succeeds in breaking out of the inoculated one. This appears to be a fairly stable characteristic of the variety—pathogenic strain combination. In order to see whether the width of the lesion really bears a relation to the resistance of a variety, 20 clumps (80 to 100 canes) of 27 varieties were selected at random for a test. These had been inoculated with the virulent ' D ' strain of the pathogen (Rafay, 1950) and examined at the end of three months. The lesion extended between five and nine internodes in the selected varieties and in width between 30 and 100% of the diameter of the stalk in the internode immediately superior to the inoculated one. Five inoculated clumps (25 canes) in each variety were left to stand in the field for a further period of two months and then examined for drying of tops and extent of tissue damage revealed by further spread of the lesions. The results are given in Table I. It was seen that irrespective of the original longitudinal spread of the lesions, varieties which had a lesion width of one half or less of stalk diameter continued to carry green tops and appeared to suffer relatively little visible damage of the tissues, while nearly all those which had wider lesions had dried-up tops accompanied by extensive tissue damage and frequently by shrunken, hollowed and desiccated canes.

It would appear that width and type of lesion, rather than either lesion length or number of affected internodes alone, have an important bearing on the degree of resistance of sugarcane varieties, and should deserve due importance in testing varietal resistance.

Acknowledgement

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ROOT APICAL ORGANIZATION IN MONOCOTYLEDONS—CANNACEAE

By S. K. Pillai and (Mrs.) Ambuja Pillai

Department of Botany, Birla College, Pilani, Rajasthan

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In a previous communication the authors (1961) have described the apical organization in the roots of some members of the family Musaceae of the order Scitamineae. This article embodies their observations on the root apical organization of some members of Cannaceae.

Materials and Methods

The methods used in the study of the members of Musaceae were followed here also. The root-tips of the following species were investigated:—

Canna indica Linn. and *Canna edulis* Ker-Gawl.

Observations

In these root apices also the organization was studied from the structural and cyto-physiological points of view.

A. Structural Organization

The root-tips of these two species show a similar structural organization. The root-cap is separate from the root body. Distinct structural initials are found at the tip of the root body.

(1) *Root-cap and Columella*

In the centre of the cap can be seen distinct longitudinal files of cells constituting the columella. The meristem giving rise to this is not contributing to the rest of the calyptra. It is composed of a few layers of cells across and in longisections is seen fitting into a depression found at the tip of the root body (Text-Figs. 4 and 7). The cells of this meristem divide transversely like a rib meristem and its derivatives elongate to the front and get vacuolated. This meristem has been named the columellogen.

Surrounding the central columella and slanting from the flanks towards it are cells oriented in oblique files. They are located outside the dermatogen. T-divisions, with the capital of the T directed towards the flanks, occur here and these enable the peripheral zone to widen out towards the tip. The meristem is called the "peripheral region" by Allen (1947) and is located outside the dermatogen.

The formation of the root-cap was studied in developing lateral roots of *Canna indica*. Only the endodermal cells are involved in its formation. These cells divide anticlinally first (Text-Fig. 1). Then periclinal divisions are seen at the middle of the row (Text-Fig. 2). These cells appear to continue such periclinal divisions whereas the cells to the flanks exhibit T-divisions. Thus, after the lateral root has developed for some time, but when it is still within the mother root, it is possible to distinguish the two patterns of cell division characteristic of the two regions of the cap. A few cells in the middle exhibit only periclinal divisions (transverse to the axis of the lateral root) constituting the columellogen whereas the cells around this show the T-type of division with the T-head located towards the hind part of the lateral root, *i.e.*, towards the stele of the mother root, constituting the peripheral region (Text-Fig. 3). Thus, the two meristems of the root-cap become separate even very early in the development of the root body.

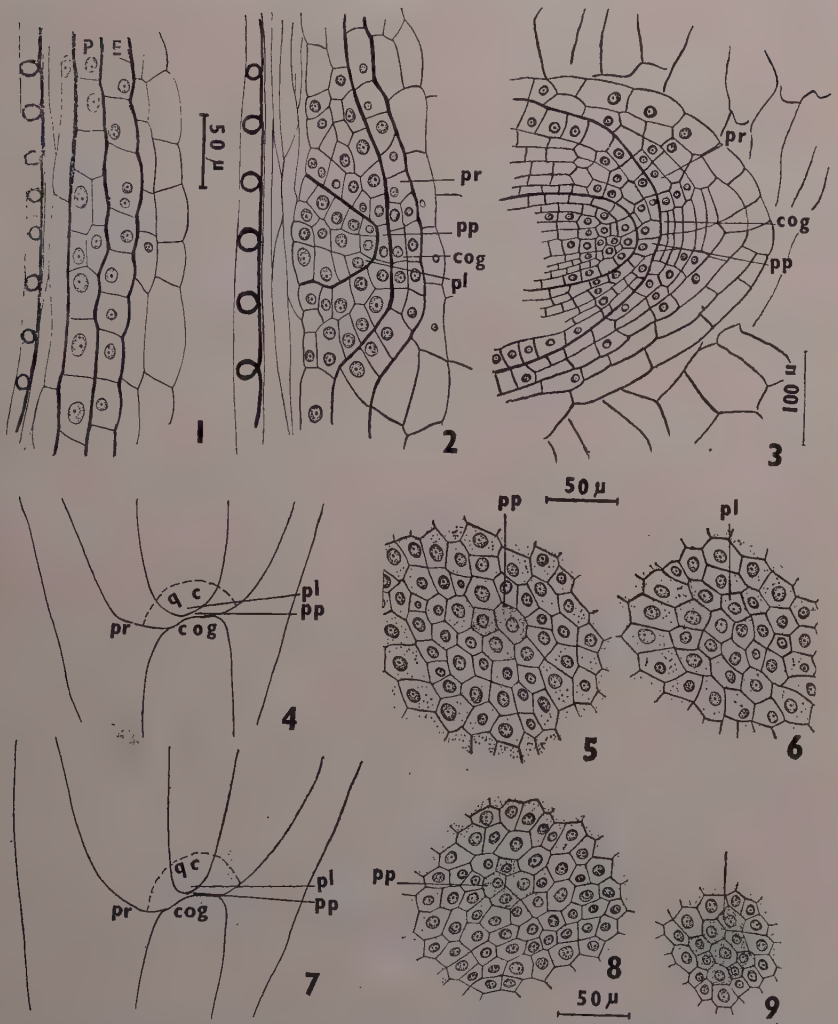
(2) *Histogens of the Root Body*

At the tip of the root body can be distinguished the plerome and outside its dome a single tier of initials which give rise to the cortex and the epidermis, called the protodermperiblem complex (Clowes, 1954; Kasapligil, 1954).

(*a*) *The Protoderm-Periblem Complex*.—As mentioned above, this is composed of one tier of about 1–5 cells (Text-Figs. 5, 8, 10 and 11). These cells undergo T-divisions on the flanks enabling this region to become wider both towards the tip and the body because of which there results a concavity into which the columellogen fits (Text-Figs. 10 and 11). This common initiating zone has been called *Dermoperiblem* by Clowes (1954) and *Protoderm-Periblem Complex* by Kasapligil (1954).

(i) *Dermatogen*.—From the products of division of the outermost layer of the derivatives of the protoderm-periblem complex separates out at some distance, a tier of the cells. This tier divides only anticlinally and gives rise to the epidermis in the older portions. This is referred to as the *dermatogen* here and so the expression is used in a restricted sense.

(ii) *Periblem*.—This includes the originating zones of the hypodermis, cortex and endodermis. In the initial stages all these have a common origin with the dermatogen. Some of the outermost derivatives of the protoderm-periblem complex undergo T-divisions. The inner of the twin daughter cells of such T divisions (Text-Fig. 10, T) by further divisions give rise to the hypodermis. The remaining cells of this complex exhibit many more T-divisions thus making the cortex wider so that oblique files of cells are formed inside the dermatogen which run in the opposite direction to those of the cap cells located outside it. The innermost file of these, bordering on the pericycle, becomes distinct after a few such T-divisions into a separate, uniseriate tissue, the endodermis. The cells of this layer from now on divide



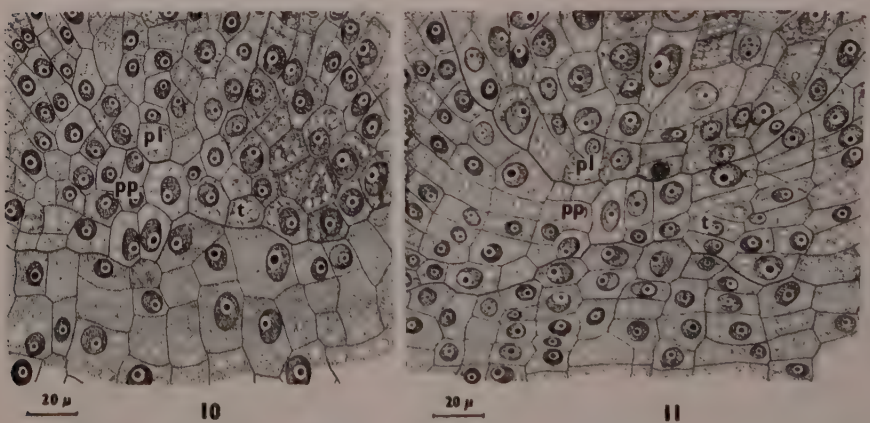
TEXT-FIGS. 1–9. Figs. 1–6. *Canna indica*; Figs. 7–9, *Canna edulis*. Fig. 1. *Canna indica*. Development of lateral root. Pericycle (P) giving rise to the root body and endodermis (E), to the root-cap. Fig. 2. A more advanced stage in the development of the lateral root where the protoderm-periblem (*pp*) and plerome (*pl*) have become clearly differentiated in the body of the root, while with the periclinal division of the middle endodermal cells, the columellogen (*cog*), and the anticlinal divisions of the endodermal cells at the sides, the peripheral region of the cap (*pr*), are formed. Fig. 3. A more advanced stage in development of the lateral root, still within the mother root. The plerome (*pl*) and protoderm-periblem complex (*pp*) are well formed. The peripheral region of the cap (*pr*) can be distinguished by T-divisions and the columellogen (*cog*) by the transverse divisions of the endodermal cells. Fig. 4. A diagrammatic sketch of the median longisection of the root apex showing the structural histogens columellogen (*cog*), peripheral region of the cap (*pr*), protoderm-periblem complex (*pp*) and plerome (*pl*). Note the concavity at the apex of the root body into which the columellogen fits; also, the quiescent centre

(*qc*) marked out is in the form of an inverted cup. Fig. 5. A transection passing through the protoderm-periblem complex, a tier of a few cells (shown stippled). Fig. 6. A transection passing through the plerome initials (shown stippled) surrounded by the cells of the quiescent centre. Fig. 7. *Canna edulis*. A diagrammatic sketch of the median longisection of the root apex showing the structural histogens columellogen (*cog*), peripheral region of the cap (*pr*), protoderm-periblem complex (*pp*) and plerome (*pl*). Note the concavity at the apex of the root body into which the columellogen fits. The quiescent centre (*qc*) marked out is in the form of an inverted cup. Fig. 8. A transection passing through the protoderm-periblem complex, a tier of a few cells (stippled). Fig. 9. A transection passing through the plerome initials (stippled) surrounded by the cells of the quiescent centre.

(Scales common for Text-Figs. 1 & 2, 5 & 6 and 8 & 9.)

mainly anticlinally. The endodermis, therefore, can be said to arise from an endodermis-periblem complex.

(*b*) *Plerome*.—The dome of this is composed of 4–5 cells across (Text-Figs. 6 and 9). The plerome is distinguishable into an outer single-layered pericycle, the cells of which have densely staining cytoplasm much nearer the dome. The pericyclic cells divide anticlinally. In the centre of the plerome there are some isodiametric cells which divide mainly transversely like a rib meristem and give rise to the medulla in the middle.



TEXT-FIGS. 10 and 11. Fig. 10. *Canna indica*. A portion of the tip of the root body enlarged with the columellogen to the outside of the protoderm-periblem complex (*pp*) and the plerome (*pl*) to its inside. *t*, T-divisions showing the beginning of the hypodermis from the outer layers of the protoderm-periblem complex. The cyto-physiological state of the cells at the tip is brought out. Fig. 11. *Canna edulis*. Details as in Text-Fig. 10.

Histogenesis of the Body of the Lateral Root.—The body of the lateral root is built up from the products of division of the pericyclic cells. These cells become dense with deeply staining cytoplasm and prominent nuclei. In the middle of this group, the cells undergo periclinal divisions (Text-Fig. 1). Even before the calyptra becomes easily distinguishable into the columellogen and peripheral region, the cells

derived from the anticlinal and periclinal divisions of the pericycle are distinguishable into the single-layered protoderm-periblem complex and the plerome (Text-Fig. 2).

Thus, the structural organization of the lateral root is exactly similar to that of the main root. But, all the cells are dense with contents and with prominent nuclei and nucleoli so that cells in a state of repose are not noticed in this early stage.

B. Cyto-physiological Organization

As in the apices of the roots of the members of Musaceae, here also could be distinguished two zones on cyto-physiological grounds. A group of cells at the tip of the root body, *i.e.*, excluding the root-cap, shaped like a cup with the broader part towards the cap, could be distinguished by their lightly stained and vacuolated cytoplasm (Text-Figs. 10 and 11), comparatively smaller nuclei and nucleoli (Table II) and lesser frequency of mitotic figures (Table I). This is the quiescent centre (Clowes, 1956 *a*). The size of the quiescent centre is found to vary, being smaller in thin and young roots and bigger and more pronounced in thick and mature roots (Table I). It includes cells of the

TABLE I

The total number of cells constituting the quiescent centre and the meristematic zone and the number and percentage of dividing cells in them (as observed in one transection each of five roots)

Species	Quiescent Centre			Meristematic Zone		
	Total no. of cells	No. of dividing cells	Percentage	Total no. of cells	No. of dividing cells	Percentage
Canna indica ..	66	2	3·03	98	17	17·34
	25	1	4·00	98	18	18·36
	45	2	4·44	97	17	17·45
	50	2	4·00	100	19	19·00
	40	1	2·50	97	17	17·45
Canna edulis ..	25	1	4·00	101	25	25·00
	67	4	5·97	115	25	21·73
	60	3	5·00	100	20	20·00
	62	3	4·90	103	23	22·33
	70	4	5·71	100	24	24·00

various structural histogens of the root body. It gradually transcends into a region behind as seen in longisections and around as seen in transections, where the cells have densely stained cytoplasm, lesser vacuolation, comparatively bigger and more prominent nucleoli and nuclei (Table II) and much greater frequency of division figures (Table I). This zone, named as the meristematic zone, also includes all the structural histogens of the root body.

The sizes of the cell, nucleus and nucleolus and the nucleolus/nucleus and nucleus/cell ratios in these two regions were calculated (Table II). These show that the cells in the latter region are synthesizing more nucleic acids and are in a better state of preparation for division. The meristematic nature of the cells is supported by the appearance of the cells of the dermatogen in the two zones. In the quiescent centre they are longer whereas in the meristematic zone they are short and densely packed one above the other like a stack of coins. This meristematic zone appears to be the actual site of initiation of new cells in such roots.

TABLE II

The areas in sq. μ of the cell, nucleus and nucleolus in the quiescent centre and meristematic zone and the respective nucleolus/nucleus and nucleus/cell ratios

(Mean of 20 determinations)

Plant species	Quiescent Centre				
	Cell	Nucleus	Nucleolus	Nucleolus / Nucleus	Nucleus / Cell
Canna edulis ..	35·42± 7·64	8·317± 1·812	0·4265± 0·0608	5·12	23·48
Canna indica ..	75·84± 28·70	14·509± 5·102	0·8038± 0·2719	5·54	19·13

Plant species	Meristematic Zone				
	Cell	Nucleus	Nucleolus	Nucleolus / Nucleus	Nucleus / Cell
Canna edulis ..	49·34± 15·53	12·219± 2·396	1·509 ± 0·0442	12·35	24·76
Canna indica ..	65·38± 22·36	14·969± 3·827	2·4845± 0·7296	16·60	22·89

Hence, though a distinct structural organization is recognizable at the apices of these roots, the cells at the extreme tip go into quiescence as the root matures and appear to be merely carried forward and to play a comparatively minor part in histogenesis.

The distances of the first appearance of the vascular elements and the first appearance of the mature phloem elements were measured in the roots of these species also and it can be seen from the values in Table III that the latter is about 200–500 μ behind the tip of the root body.

TABLE III

The levels of origin of metaxylem, protoxylem and phloem and the level of appearance of mature phloem elements from the tip of root body

Species	Level of origin of			Level of appearance of mature phloem μ
	Metaxylem μ	Protoxylem μ	Phloem μ	
Canna indica ..	160	390	310	500
Canna edulis ..	45	85	70	200

DISCUSSION

The structural organization at the root apices falls under type 2 of Janczewski (1874), Treub (1876), Haberlandt (1914), Hayward (1938), Popham (1952) and Esau (1953). This type, according to them, is found mainly in grass-root apices. But, investigations by the authors show that this is found in the members of Cannaceae being reported here and in the members of Zingiberaceae and Marantaceae to be reported later. Esau (1953) does not mention this type of organization as occurring among Monocotyledons at all, whereas Popham (1952) mentions it as the principal monocotyledonous type, although the examples that he quotes are mainly from among the Gramineae. It appears that this is an important type of structural organization among Monocotyledons.

Van Tieghem and Douliot (1888) noted a one-layered condition from where the dermatogen and periblem arose, which they named *epistele*. Such a tier of initials which is common to the two histogens has been referred to by Schade and Guttenberg (1951) and Clowes (1954) as the "periblem-dermatogen complex" and by Kasapligil (1954) as the "protoderm-periblem complex".

Root-Cap Formation

Hanstein (1868) and Haberlandt (1914) considered the cap to be a proliferation of the dermatogen and do not attribute its origin to the activity of any separate histogen. In these roots the cap has an inde-

pendent origin. Holle (1876) assigned roots of all plants to two categories on the basis of the mode of root-cap formation:—

(i) those whose root-caps originate from an apical cell, and

(ii) those whose root-caps arise from the 'periblem'.

The possibility of an independent histogen for the formation of this portion has not been visualized by Holle. In these two species of *Canna*, the cap arises from a separate meristematic layer which has no genetic connection with the main body of the root. This is distinguishable into a central columella and a peripheral zone.

The central columella has been distinguished from the rest of the cap even from very early times. Holle (1876) and Eriksson (1878) called it the ' saule' and the 'kolonne' respectively. Schüepp (1926) also called it the 'saule'. Zirkle (1932) calls it the 'core'. Neumann (1939) and Guttenberg (1941) call it the 'kolumella'. Johansen (1941) proposed a new term, the 'stalace' for this region. Recent investigators like Schopf (1943), Allen (1947), Spurr (1949), Kasapligil (1954) and others also recognize the columella in the cap.

As to the meristem which gives rise to the columella, no particular mention is made by most of these authors. The assumption seems to be that the calyptrogen gives rise to the columella also and fundamentally this can be considered to be its mode of origin. Tiegs (1913) seems to be the first to recognize separate initials for the columella from the rest of the initials for the cap. Later authors like Schopf (1943), Allen (1947), Spurr (1949) and Kasapligil (1954) all recognize the cap to have two separate regions of initials, one set for the columella in the centre and the other for the region around it which Allen (1947) has termed the 'peripheral region'. Wagner (1939) and Clowes (1954) have brought out that the formation of the columella in broad root apices is independent of the rest of the cap. But they too have not mentioned the histogen which gives rise to the columella. Since it has been found by most investigators that from a structural point of view a modified histogen theory can be applied, and since the initial zone appears to be concerned with the formation of the columella files only, the authors venture to give it the name 'columellogen' and adopt the terminology of Allen (1947) for the rest of the cap initials namely the 'peripheral region'. When the origin of the histogens of the root-cap is traced in the lateral roots, the two histogens of the root-cap become distinguishable very early in development by the patterns of their cell division, one transversely and the other by T-divisions. Therefore, it appears justifiable to designate the two regions as two separate histogens and to use terms also to distinguish them.

Histogens of the Root Body

Dermatogen.—This arises from the protoderm-periblem complex and this term is used in a restricted sense only as reported earlier by the authors in the case of members of Musaceae (1961). According to

Hanstein (1868) dermatogen and protoderm are not synonymous terms. Protoderm refers to the outermost layer of the apical meristem and may give rise to the epidermis only or to the subepidermal layers also, whereas the dermatogen has its own initials and generates the epidermis only. So, protoderm comprehends something more than the epidermis and is used in the expression 'protoderm-periblem complex' in that sense.

Esau (1953) states that in roots "the dermatogen is supposed to be the outermost layer of the cortex". In these roots this layer separates out from the same initials as for the cortex, which type has been called by Clowes (1953) as arising from the cortex complex.

Endodermis.—Haberlandt (1914, pp. 391–92) states "the ontogenetic origin of the endodermis is quite as variable as its phylogenetic development". He has demonstrated the procambial origin of the endodermis in Juncaceae and Cyperaceae. Eames and MacDaniels (1947, p. 160) also mention that the endodermis has been considered as both the innermost layer of the cortex and the outermost layer of the stele. However, it has not been described as arising from an independent histogen like the uniseriate dermatogen for the epidermis. In these plants the endodermis arises from the cortex complex. Near the plerome dome the innermost layer of periblematic cells exhibit T-divisions, from the products of which separates out the endodermis. If we consider this meristem as the one concerned with the formation of the endodermis, then the cells are cut off not only to form the endodermis but also to form the periblem. Williams (1947) and Beckel (1956) have reported this type of meristematic activity and consider the endodermis to be meristematic in the early stages. But, the endodermis arises from a common initial zone for the periblem and endodermis like the one for the dermatogen and periblem towards the outside and so it may be said that it arises from an endodermis-periblem complex.

Plerome.—Initials for this are normal in their activity giving rise to the pericycle, vascular elements and pith.

Histogenesis of the Lateral Root

The pericycle is exclusively concerned with the development of the histogens of the body of the lateral root. Eames and MacDaniels (1947, p. 163) say that "the initials of the lateral roots and of adventitious roots commonly arise in the endodermis". Esau (1953, p. 499) states "that apical meristem (of the lateral root) has not necessarily the same architecture as that of the parent root, but it may develop such with further growth". The authors find that in the roots of *Canna indica* there is no difference in the architecture of the lateral and parent roots.

Cyto-physiological Organization

In these roots also it is found that the cells, at the extreme tip of the root body in the shape of a cup, are in a state of repose exhibiting

(i) lightly stained cytoplasm, (ii) vacuolation (Text-Figs. 10 and 11), (iii) smaller nuclei and nucleoli (Table II), (iv) lesser frequency of division figures (Table I) and (v) smaller nucleolus/nucleus and nucleus/cell ratios as compared with the cells around them. In these roots where the root-cap is separate, it is possible to distinguish clearly that this region, the quiescent centre (Clowes, 1956 *a*, *b*; 1958 *a*, *b*), does not extend to the root-cap unlike that in Musaceae, where such a clear distinction was not possible. The region behind it as seen in longisections and around it, as seen in transections, is the meristematic zone which appears to be the real site of histogenetic activity. This also recalls the similarity with the postulation of the *meristeme d'attente* and *anneau initial* by the Plantefol school (Plantefol, 1947; Buvat, 1952) which was pointed out before.

These studies indicate that the cyto-physiological state of the cells of these two regions at the apex appears to have more importance on histogenesis at the root apices than the structural organization.

In these roots also the distances behind the tip of the root body at which the phloem elements mature was measured (Table III). This is found to be 200–500 μ behind. This supports the suggestion that the cells of the quiescent centre go into that state because of the lack of sufficient nutrients.

Lateral root.—From the cyto-physiological point of view there is no difference in the various cells constituting the extreme tip of the lateral root, all the cells being active. It appears that a quiescent centre develops as the roots grow older and mature. Also the size of the quiescent centre is found to increase as the roots grow thicker (Table I).

Summary and Conclusions

The root apices of two species of *Canna* exhibit a structural organization with discrete initials for cap and plerome and a common initial zone for the protoderm and periblem.

The initials of the root-cap can be distinguished into two regions. The one in the middle fits into a depression at the tip of the root body and is characterised by cutting off cells only transversely to the front to form the columella. The name columellogen which was given earlier is continued to be applied to this. The other, characterised by T-divisions, is concerned with formation of the sides of the cap, called the peripheral region.

The origin of the endodermis is traced to an initial zone common with the periblem named here as the endodermis-periblem complex.

The cyto-physiological state of the cells at the root apices has been studied which brought out that there is a quiescent centre at the extreme tip of the root body and around and behind it is the real histogenetic zone called the meristematic zone. The characteristics of the cells composing these two zones are described. The importance of the cyto-physiological state of the root apices in histogenetic studies is stressed.

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* Originals not seen.

REVIEWS

Bulletin of the Botanical Society, College of Science, Nagpur. Vol. II. No. 1, pages 1–79. 1961. Published by the Botanical Society, College of Science, Nagpur.

This Bulletin is published by the Botanical Society of the College of Science, Nagpur. The Editorial Board consists of the Editor, Shri M. V. Mirashi and three Counsellors.

In the present issue there are seven papers covering various branches of Botany like Embryology, Taxonomy, Cytology, Ecology and Mycology. Of these, three papers relate to descriptive embryology and these have been fairly well written. There is a review article on Kinetochore and a paper on Taxonomy pertaining to the Tubiflorae of Nagpur. The remaining two papers on Ecology and Mycology are on seed study of *Anogeissus latifolia* Wall., and a contribution to the Safflower Rust *Puccinia carthami* (Hutz.) Corda respectively.

While it is most welcome to have more scientific journals for a vast country like India, it is also essential that the get-up of a scientific journal of this nature should be *par excellence*. The paper used and the printing are rather poor and in the first thirty-two pages the printing impression is seen even on the back side of these pages. Better quality art paper should be used for printing photographs. The printing and general get-up of the Bulletin is thus far from satisfactory and requires great improvement. Under Instructions to Contributors the name of the present Bulletin is abbreviated thus: *Bull. Bot. Soc. Col. Sci. Nag.*; but to be in conformity with the international convention it should be *Bull. bot. Soc. Coll. Sci. Nagpur*. The exact date of publication for each issue should also be indicated.

This attempt in starting a new Journal is praiseworthy and we hope it will soon establish itself well and serve as a useful medium for the dissemination of botanical knowledge.

K. Subramanyam.

Studies in Palaeobotany. By Henry N. Andrews, Jr., 1961. John Wiley & Sons, Inc., New York and London. Pp. 487.

In recent years palaeobotany has made rapid progress in many directions. Professor Andrews' text-book reflecting some of these recent trends is, therefore, to be warmly welcomed. The book is meant for advanced students of Botany and Geology. The style of writing is smooth and so fluently expository, with none of the dryness so characteristic of many text-books, that many will find it a stimulating reading.

The arrangement of subject-matter is different from the usual text-books on palaeobotany. The author has tried to arrange the material in an evolutionary sequence, as he believes it, beginning with the psilophytes and following through the coenopterid ferns, pteridosperms and angiosperms. These are dealt with in Chapters II to VII. Then follow lycopods, sphenopsids, cycads, conifers and ginkgophytes. In the matter of classification the outlook here is a polyphyletic one. A separate chapter is given to the fossil bryophytes. An interesting feature for the morphologists is that in several chapters a section is reserved for some problematical but highly interesting plants; entire Chapter XII is so devoted.

After dealing with most of the fossil plant groups, the author goes on to give us an interesting account on the fossil floras of the Arctic and Antarctic, a subject which always had a special fascination for botanists and geologists. A separate chapter, although the account is rather brief, is devoted to some of the more important late Palaeozoic and early Mesozoic floras, including the Glossopteris flora of the Asiatic and Southern regions. There are several attractive problems centered around the origin of the seed. In Chapter XIII under the heading " Heterospory and the evolution of the pteridospermous seed " the author presents his well-argued concept on how the seed must have originated. In the last chapter is included an outline of certain of the more useful palaeobotanical techniques.

The rapidly expanding field of fossil spores and pollen is a branch of palaeobotany in its own right and finds a place in the book. Dr. C. J. Felix has contributed a separate account which will serve as a brief introduction.

Illustrations are excellent and many of them are new. The references cited at the end of each chapter and on pages 473–75 are a particular asset of the book.

The book is well produced and will be found indispensable by many wishing to keep abreast of this rapidly expanding science.

K. R. SURANGE.

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THE INDIAN BOTANICAL SOCIETY

PROCEEDINGS
OF THE
ANNUAL MEETING, 1961

BANGALORE CITY
PRINTED AT THE BANGALORE PRESS, MYSORE ROAD
1961

THE INDIAN BOTANICAL SOCIETY

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1924	Prof. M. A. Sampath-kumaran		Prof. R. H. Dastur
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THE INDIAN BOTANICAL SOCIETY
MINUTES OF THE ANNUAL GENERAL BODY MEETING

THE FORTIETH ANNUAL GENERAL BODY MEETING of the Indian Botanical Society was held in the Ground Floor Class Room of the W.R.D.T.C. Building, Roorkee, on 3rd January 1961, with Dr. E. K. Janaki Ammal, the Vice-President of the Society, in the Chair.

The following members and a large number of visitors attended the meeting:—

Prof. C. V. Subramanian, Dr. K. A. Chowdhury, Dr. R. Seshagiri Rao, Dr. K. S. Bhargava, Prof. P. N. Mehra, Dr. G. P. Agarwal, Dr. K. Subramanyam, Dr. M. A. Rau, Mr. B. S. Venkatachala, Dr. K. B. Deshpande, Dr. P. N. Nandi, Dr. S. Chitaley, Dr. V. R, Dnyansagar, Mr. Ramesh Rao, Mr. S. N. Bhambie, Dr. S. P. Mittal, Mr. R. K. Gupta, Mr. M. S. Tayal, Dr. E. K. Janaki Ammal, Prof. J. Venkateswarlu, Dr. P. D. Varada Rajan, Dr. Y. S. Murty, Dr. M. R. Sharma, Mr. K. L. Maheshwari, Mr. S. Ramam, Mr. R. K. Gupta, Mr. I.P. Bahri, Dr. S. K. Saksena, Prof. Y. Bharadwaja, Mr. B. S. Ahuja, Mr. S. K. Jain, and Mr. Rangaswamy Ayyangar.

1. The following condolence resolutions were moved from the Chair and passed by the members, all standing in silence:

> "It is *resolved* to place on record the Indian Botanical Society's sense of profound sorrow at the sad demise of Prof. S. P. Agharkar, a former President of the Society, who served the cause of Indian Botany and Science in various capacities. Further it is *resolved* to convey the Society's sympathy to the members of the bereaved family."
>
> "The Indian Botanical Society places on record their sense of shock and sorrow at the tragic death of Dr. D. Chatterjee, a Member of the Society and the Superintendent of the Indian Botanic Gardens, while actively attending to his duties. It is also *resolved* to convey Society's heartfelt condolences to the members of the bereaved family."
>
> "The Indian Botanical Society places on record its profound sense of sorrow at the sad demise of Prof. M. S. Sayeed-ud-Din, a Member of the Society and Professor of Botany, Osmania University, Hyderabad. It is also *resolved* to convey the Society's heartfelt condolences to the bereaved family."
>
> "It is *resolved* to record the Society's sense of grief at the sudden passing away of Prof. S. K. Pandé, a former President of the Society and Professor of Botany, University of Saugor. It is *further resolved* to convey the Society's heartfelt condolences to the bereaved family."

2. The minutes of the 39th Annual General Body Meeting held at Bombay on 3rd January 1960 were read and confirmed.

3. The Annual Report of the Society for the year 1960 was read by Prof. J. Venkateswarlu, Hon. Secretary, and it was adopted unanimously.

4. The Budget Estimates for the year 1961–62 and the Audited Statements of Account for the period 1–4–1959 to 31–3–1960 already circulated to the members as Proceedings of 1960 were presented by Prof. J. Venkateswarlu, Hon. Secretary, Indian Botanical Society, in the absence of Prof. T. S. Sadasivan, Treasurer and Business Manager of the Society, and the same were considered and approved.

5. The letter dated November 9, 1960, from Dr. E. K. Janaki Ammal suggesting that a minimum qualification in Botany should be there for admission of persons to the membership of the Society was considered. Most of the members were in agreement about the desirability of restricting the admission to the Society to persons at least with a B.Sc. qualification. However, there were a very few persons who were in favour of keeping it open to all those interested in Botany according to the present rules. It was pointed out that, for consideration of the matter, there should be a resolution giving the due notice according to the Rule No. 38 of the Society for taking decision and therefore it was left to the members to send a resolution in time according to the rule for consideration at a future Annual Meeting of the Society.

6. A letter dated March 18, 1960, from Prof. P. Parija, suggesting a separate Botanical Conference at a place other than the venue of the Science Congress was considered. Such a Conference was thought to be very desirable by the members and they welcomed the idea. Dr. G. S. Puri pointed out that there should be a committee to organise and on this committee there should be members representing Societies established in different branches of Botany such as Ecological Society, Plant Physiology Society, etc. Prof. P. N. Mehra expressed that the matter should also be discussed with the President of the Botany Section of the Science Congress and the General Secretary of the Science Congress so that the two Conferences may not be overlapping and duplication in the work and functions of these two bodies may be avoided.

7. (*a*) A proposal unanimously put forward by the Executive Council to elect Prof. D. G. Catcheside, M.A., D.Sc., F.R.S., Professor of Microbiology, the University of Birmingham, as an Honorary Member of the Society was considered and it was unanimously *resolved* to elect him as the Honorary Member with effect from 1961.

(*b*) The following applicants were admitted to the Society as new members subject to their payment of admission fee and annual subscription:—

1. Mr. N. K. Lakshmanan, Nilgiris.
2. Mr. Siva Sankar Prasad, Muzzaffarnagar.

3. Mr. M. K. Prasad, Ernakulam.
4. Mr. R. K. Pillai, Trichinophly.
5. Mr. M. K. Thoke, Kawardha.
6. Mr. Someswaranath Bhargava, Allahabad.
7. Dr. V. Sitarama Das, Tirupati.
8. Mr. V. C. Ganapatrao, Bhuj.
9. Mr. Hari Om Saxena, Dehra Dun,
10. Mr. Roopkumar Issar, Dehra Dun.
11. Dr. N. J. Hrishi, Lund, Sweden.
12. Dr. P. D. Varada Rajan. Ahmedabad.
13. Dr. D. C. Mitra, Lucknow.
14. Dr. G. S. Murty, Rajahmundry.
15. Dr. S. K. Saxena, Aligarh.
16. Dr. Sandhya Mitra.

8. The Presidential Address, sent by Dr. I. Banerji, President, for the year, was read by Prof. J. Venkateswarlu, Hon. Secretary, as Dr. I. Banerji could not attend owing to reasons of health.

9. The results of the election for the year 1961 as given below were announced by the Secretary:—

President: Prof. J. Venkateswarlu, Waltair.

Vice-Presidents: (1) Dr. I. Banerji, Calcutta; (2) Prof. P. N. Mehra, Chandigarh.

Hon. Secretary: Prof. V. Puri, Meerut.

Hon. Treasurer and Business Manager: Prof. T. S. Sadasivan, Madras.

Councillors: (1) Dr. I. Banerji, Calcutta; (2) Dr. P. Parija, Cuttack; (3) Dr. A. C. Joshi, Chandigarh; (4) Prof. S. Ranjan, Allahabad; (5) Prof. V. Puri, Meerut; (6) Prof. T. S. Mahabale, Poona; (7) Prof. R. P. Roy, Patna; (8) Rev. Fr. H. Santapau, Calcutta; (9) Prof. S. N. Das Gupta, Lucknow; (10) Mr. M. B. Raizada, Dehra Dun.

10. The retiring Office-bearers were appropriately thanked on a motion by the Hon. Secretary, Prof. J. Venkateswarlu. The President thereupon thanked the Hon. Secretary for his services to the Society.

The authorities of Roorkee University and the Indian Science Congress Association were thanked for all the help rendered by them in connection with the meetings and functions of the Indian Botanical Society.

A group photograph of the members of the Indian Botanical Society present was taken on 5th January 1961.

ANNUAL REPORT FOR THE YEAR 1960

THE Executive Council of the Indian Botanical Society have pleasure in submitting the following report for the year 1960:—

1. The 39th Annual General Body Meeting of the Society was held on 3rd January 1960, at 2–15 P.M., in the Convocation Hall, University of Bombay, Bombay.

The Minutes of the meeting are being published as proceedings of the Indian Botanical Society in Volume 39 (No. 3) of the *Journal of the Indian Botanical Society* for the year 1960–61.

According to the result of the Election, the following authorities were constituted for the year 1960:—

President: Dr. I. Banerji.

Vice-Presidents: Dr. E. K. Janaki Ammal; Prof. R. Misra.

Hon. Secretary: Prof. J. Venkateswarlu.

Treasurer: Prof. T. S. Sadasivan.

Editor-in-Chief: Prof. T. S. Sadasivan.

Councillors: Dr. I. Banerji; Dr. A. C. Joshi; Prof. S. N. Das Gupta; Prof. T. S. Mahabale; Dr. P. Parija; Mr. M. B. Raizada; Prof. S. Ranjan; Prof. R. P. Roy; Prof. V. Puri; and Rev. Fr. H. Santapau.

Business Manager: Prof. T. S. Sadasivan.

Members of the Editorial Board: Dr. A. C. Joshi; Rev. Fr. H. Santapau; Prof. P. Maheshwari; and Dr. B. P. Pal.

2. A meeting of the Executive Council was held in the Syndicate Hall, University of Bombay, Bombay, on 2nd January 1960, at 3 P.M. Matters relating to the publication of *History of Botanical Research in India, Burma and Ceylon* and *Vegetational Types of India* were discussed and it was *resolved* that the publication of these articles be expedited and at least three more issues (items No. 4, 9 and 12) of the series be brought out during 1960–61 and the rest during 1961–62.

3. A meeting of the Editorial Board of the *Journal of the Indian Botanical Society* was held in the Room No. 29 of the K.C. College, Bombay, on 2nd January 1960, at 12 NOON, under the Chairmanship of Dr. A. C. Joshi. Prof. T. S. Sadasivan was elected as Editor-in-Chief and Business Manager for the year 1960.

4. A group photograph of the members of the Indian Botanical Society, who attended the Annual Meetings, was taken on 5th January 1960, at K.C. College, Bombay.

5. In accordance with the conditions of the generous endowment made by Prof. T. S. Sadasivan, the Executive Council has decided to award the Birbal Sahni Medal for the year 1960 to Dr. E. K. Janaki Ammal for her outstanding contributions in Cytogenetics and for her services to the cause of the Indian Botany.

6. The following were published during the year:—

Vol. 39 [Nos. 1, 2, 3 (already mailed) and 4 (in Press)].

7. Membership:—

Honorary Members	..	12
Life-Members	..	101
Ordinary Members	..	396
TOTAL	..	507
Admissions during 1960	..	36
Resignations during 1960	..	2
Not of good standing	..	16

8. Subscribers:—

India	..	146
Foreign	..	78
Exchange	..	52